SR 308 MP 1.15 Big Scandia Creek (15.0280 1.00):

Preliminary Hydraulic Design Report

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ROLES AND RESPONSIBILITIES FOR THIS PHD

The roles and responsibilities of the key individuals in developing this Preliminary Hydraulic Design (PHD) are defined as follows for the Olympic Region GEC:

PHD Lead PE

Responsibility: Water Resources Professional Engineer in responsible charge of this Hydraulic Design Report, including all information, calculations, assumptions, modeling, professional judgment, and commitments contained in the main report and appendices.

Authoring Firm PHD QC Reviewer(s)

Responsibility: Qualified independent individual(s) responsible for the detailed checking and reviewing of hydraulic and stream design documents prepared by the authoring firm, including all information, calculations, assumptions, modeling, professional judgment, and commitments contained in the main report and appendices. Before submittal to the GEC, the authoring Firm Quality Control (QC) Review shall be performed in accordance with the QC methods identified in the quality assurance document Technical Verification Form (TVF). The QC methods are defined in the Olympic Region GEC Quality Management Plan (QMP) Section 5.3 and the QMP Supplement developed specifically for Y-12554 Task AC.

Olympic Region GEC Fish Passage/Stream Design Advisor

Responsibility: Water Resources Professional Engineer providing mentorship, process oversight, quality check issue resolution, and recommendations in the approach to hydraulic analysis and design performed by the **PHD Lead PE**. Before submittal of draft deliverables from the GEC to either the PHD Lead or WSDOT Headquarters, the Olympic Region GEC Fish Passage/Stream Design Advisor will review and refine GEC comments and confirm GEC comment resolution by the **PHD Lead PE**.

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1 Introduction

To comply with United States et al. vs. Washington, et al. No. C70-9213 Subproceeding No. 01-1 dated March 29, 2013 (a federal permanent injunction requiring the State of Washington to correct fish barriers in Water Resource Inventory Areas [WRIAs] 1 through 23), the Washington State Department of Transportation (WSDOT) is proposing a project to provide fish passage at the State Route (SR) 308 crossing of Big Scandia Creek at milepost (MP) 1.15 within WSDOT's Olympic region. The existing structure at that location has been identified as a fish barrier by the Washington Department of Fish and Wildlife (WDFW) and WSDOT Environmental Services Office (ESO) (site identifier [ID] 15.0280 1.00) and has an estimated 26,581 linear feet (LF) of habitat gain.

Per the federal injunction, and in order of preference, fish passage should be achieved by (1) avoiding the necessity for the roadway to cross the stream, (2) use of a full-span bridge, or (3) use of the stream simulation methodology. WSDOT evaluated the crossing using the unconfined bridge method because the channel was found to be unconfined. SR 308 is an essential access road to rural communities including Keyport in Kitsap County and cannot be avoided.

The crossing is located in Kitsap County, 2 miles west of Keyport, Washington, in WRIA 15. The highway runs in an east-west direction at this location. Big Scandia Creek generally flows from the northwest to the southeast beginning 2 miles upstream of the first SR 308 crossing at culvert ID 990235. From there, the stream makes a U-shaped turn and flows from south to north through the SR 308 crossing. Big Scandia Creek continues approximately 6,000 feet north to Liberty Bay (see Figure 1 for the vicinity map).

The proposed project will replace the existing 72-inch-diameter, 292-foot-long corrugated metal pipe (CMP) with a structure designed to accommodate a minimum hydraulic width of 30 feet. Structure type has not been recommended by WSDOT Headquarters Hydraulics at this preliminary stage but will be determined by others at future design phases. The proposed structure is designed to meet the requirements of the federal injunction using the unconfined bridge design criteria as described in the 2013 WDFW *Water Crossing Design Guidelines* (WCDG) (Barnard et al. 2013). This design also meets the requirements of the WSDOT *Hydraulics Manual* (WSDOT 2022a).

The SR 308 Big Scandia Creek crossing is one of multiple crossings of SR 308 and will be distinguished from other crossings by reference to the Site ID 15.0280 1.00 presented in the WDFW Fish Passage and Diversion Screening Inventory Database (WDFW 2019).

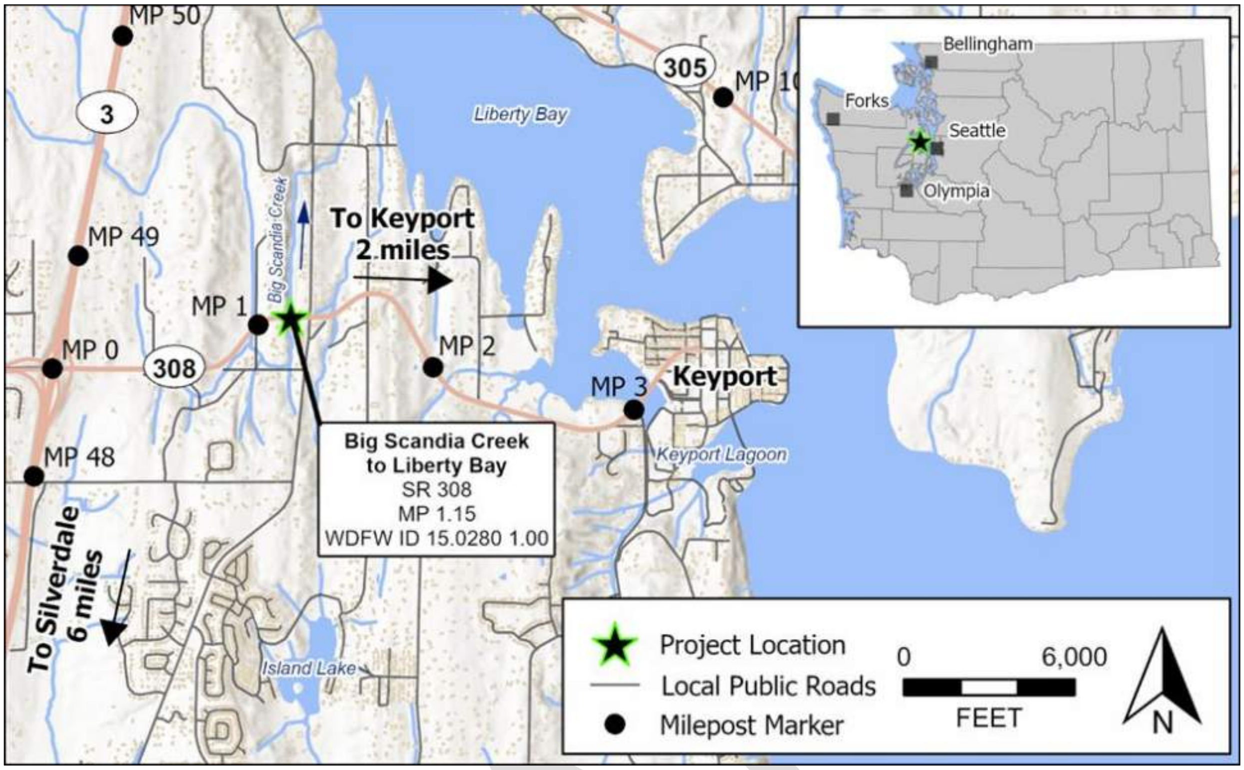

Figure 1: Vicinity map

2 Watershed and Site Assessment

The existing watershed was assessed in terms of land cover, geology, regulatory floodplains, fish presence, site observations, wildlife crossing priority, and geomorphology. This was performed using a site visit and desktop research with resources such as the United States Geological Survey (USGS), Federal Emergency Management Agency (FEMA), and WDFW, and past records like observations, maintenance, and fish passage evaluation. All elevations detailed in this report, unless detailed otherwise, are referenced against the North American Vertical Datum of 1988 (NAVD88).

2.1 Site Description

The culvert under SR 308 at MP 1.15 (Site ID 15.0280 1.00) for Big Scandia Creek to Liberty Bay is listed as a barrier by WSDOT due to the depth of flow through the existing culvert. The WDFW Fish Passage and Diversion Screening Inventory Database (WDFW 2019) describes the culvert as having 12 canted wooden baffles and a single gabion control basket downstream of the culvert, as noted by an August 1999 culvert investigation. A later investigation in 2007 notes that at that time the gabion control and some of the baffles were no longer observed at the site. At least one baffle was observed during the 2022 field visit. Due to the lack of effective control structures, the depth of flow within the culvert is shallow and has been given a 67 percent passability rating within the WDFW Fish Passage and Diversion Screening Inventory Database. Fish crossings need an appropriate depth of water to allow for fish to pass through the crossing; the existing conditions at the crossing inhibit the ability of adult and juvenile fish to access habitat upstream of the crossing.

This crossing is not listed as a Chronic Environment Deficiency (CED) or failing structure (WSDOT 2020). Maintenance records were requested from the WSDOT Project Engineer's Office (PEO) in January 2022, but no maintenance records for the culvert were available. However, as-builts and maintenance overlay records were provided. There do not appear to be any issues related to sediment deposition or flooding in the vicinity of the existing culvert. Distinct high-water marks were not evident during the site visit. The site has a potential habitat gain of 21,096 LF according to the WDFW Fish Passage and Diversion Screening Inventory Database (WDFW 2019).

2.2 Watershed and Land Cover

Big Scandia Creek has no major tributaries and drains approximately 2.1 square miles of a relatively undeveloped area located within the Kitsap Peninsula (see Figure 2). The watershed contributing to the existing culvert was delineated using Geographic Information Systems (GIS) software and topographical data obtained from light detection and ranging (LiDAR) survey data. The creek flows through a lightly forested area mixed with light residential development. The basin extends from a highpoint near Trepang Road to the west and to Viking Way to the east. The basin area has gentle slopes from the headwaters of the stream in the west and transitions to deep valleys east of SR 3 to Liberty Bay. Aerial photos from Google Earth (Google Earth 2021) show that the contributing watershed is a mix of urban and forested land. According to the USGS National Land Cover Database for 2019 (NLCD 2019), basin landcover is 39 percent developed (open space to medium density); 54 percent forested (deciduous, evergreen, and mixed); 2 percent wood wetlands; and 5 percent grassland, shrubs, and pasture (see shading on Figure 3). Table 1 presents a detailed estimate of the land use percentages. The wooded areas and low-density development are dispersed throughout the basin.

The basin's minimum and maximum elevations with respect NAVD88 is approximately 130 feet and 450 feet, respectively. The overall basin has mild slopes that average less than 10 percent. The crossing itself has an average slope of about 1.5 percent. The basin receives an annual average of 42.5 inches of precipitation (PRISM Climate Group 2021).

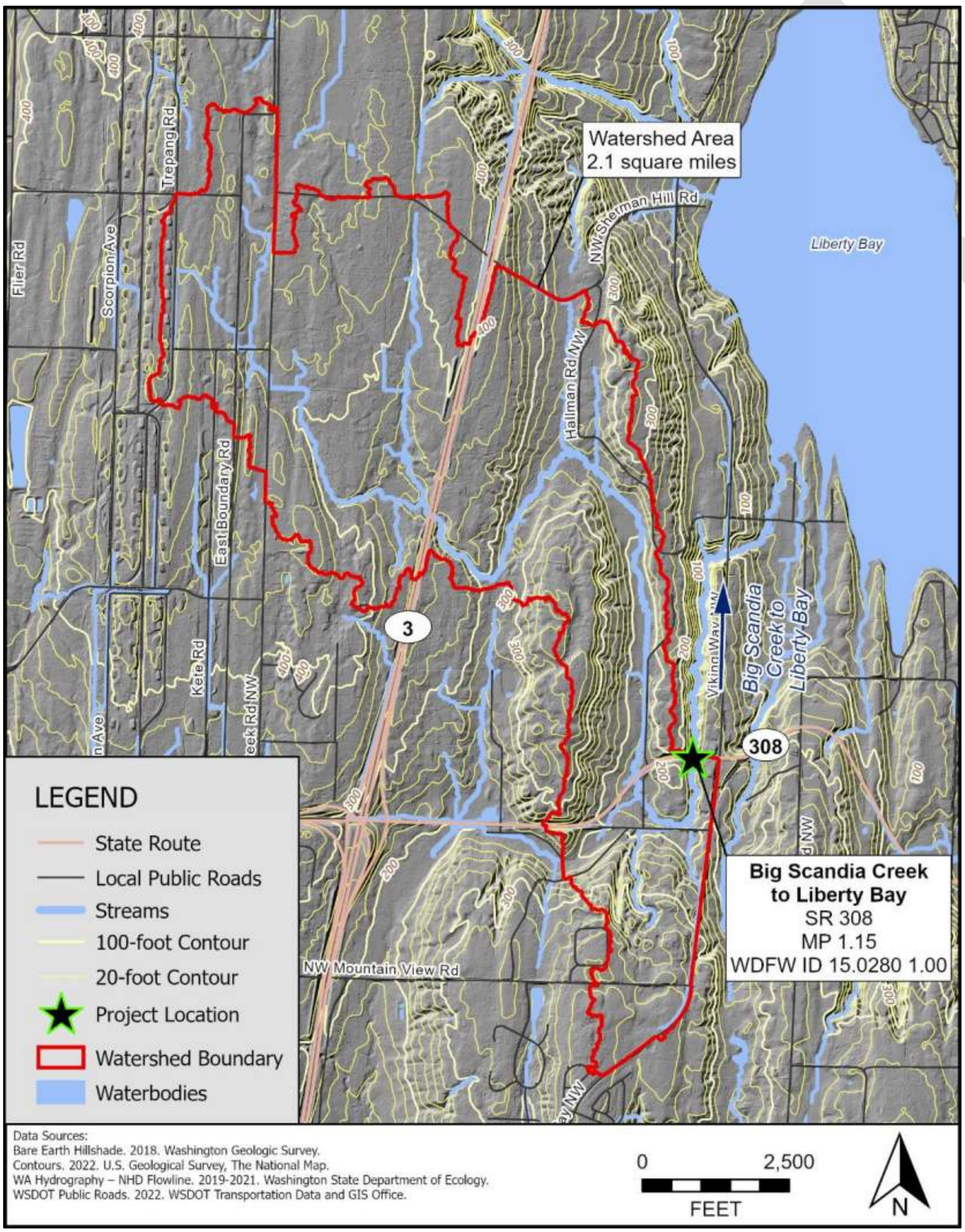

Figure 2: Watershed map

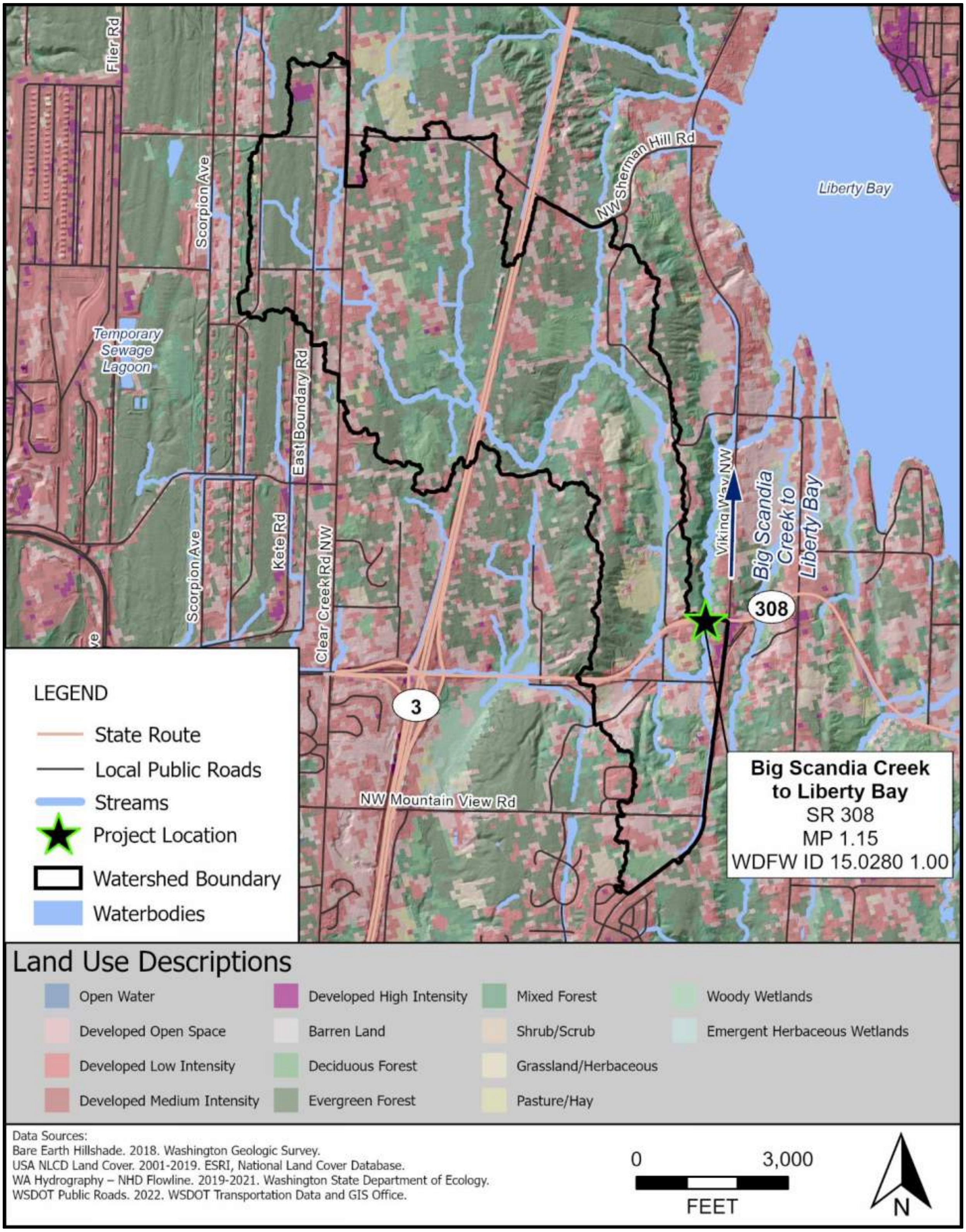

Figure 3: Land cover map (NLCD 2019)

Table 1: Land cover

Land cover class	Basin coverage (percentage)
Developed Open Space	19%
Developed Low Intensity	15%
Developed Medium Intensity	5%
Deciduous Forest	8%
Evergreen Forest	31%
Mixed Forest	15%
Shrub/Scrub	1%
Grasslands	2%
Pasture	2%
Woody Wetlands	2%

2.3 Geology and Soils

Site 15.0280 1.00 is located on the Kitsap Peninsula, which consists of glaciated surfaces that are fluted with multiple parallel ridges (gf) and pockmarked with irregular depressions (gp) (see Figure 4). This Puget Lowlands topography is shaped by glacial and non-glacial processes (Haugerud 2009). The glaciers eroded and deposited material with each advance and retreat. The last ice sheet retreated approximated 16,400 calculated years before present (Porter and Swanson 1998). Pleistocene continental glacial till is the primary geologic unit deposited in the upper basin (DNR Geology Portal 2022). Glacial till consists of clay, silt, sand, gravel, cobbles, and some boulders. The lower basin is underlain by Pleistocene glacial drift, which, like till, consists of clay, silt, sand, gravel, cobbles, and some boulders that were deposited by glacial melt water. Non-glacial deposits include alluvium and colluvium from fluvial and hillslope transport. Urbanization of the watersheds has increased runoff and sediment supply to the streams. General geology for Puget Sound Lowlands includes frequent landslides, and these landslides also add to the sediment supply. This basin is no exception and is expected to have sediment contributed to the channel from local landslides. However, the low gradient present throughout the valley retards some of the sediment transport as it progresses toward Liberty Bay (see Figure 5).

The United States Department of Agriculture, Natural Resources Conservation Service Soil Survey (2022) indicates soils in the watershed contributing to the existing culvert are dominantly loamy soils. Alderwood gravelly sandy loam comprises approximately 80 percent of the watershed. These soils comprise the top layer of the glaciated surface, so they are in the upper reaches of the watershed. In the gullies formed during the glacial outwash period, the soils consist of Kitsap and Norma silt loams. These soils comprise only approximately 5 percent of the watershed, but they dominate within the actual channel and adjacent landscape within the eroded valleys. Silt loams are primarily composed of silts, clay, and very find sands. Consequently, these soils are rather cohesive. Dystric Xerorthents are located in the stream channel upstream of the site. These soils make up only 0.6 percent of the basin and are characterized as somewhat excessively drained soil formed in glacial outwashes (see Figure 6 for the soils map). These soils indicate a steady supply of mobile material that can be expected to pass through the project site by typical sediment transport processes.

The WSDOT Headquarters (HQ) Geotechnical Scoping Lead provided additional geotechnical data dated November 22, 2021. The additional data included three historical geotechnical borings conducted at the site in 1979. The borings on the inlet side of the crossing (J-4 and J-5) were drilled to depths of 31.5 feet and 35.1 feet respectively. The boring on the outlet side of the crossing (J-3) was drilled to a depth of 31 feet. All borings encountered silty sand to silt with varying amounts of gravel in the upper 15 feet. Both borings J-3 and J-4 encountered wet conditions from the ground surface. Samples from J-5 were relatively dry. Boring sites J-3 and J-4 had ESU-2 (Engineering Stratigraphic Unit) for a depth of about 3.5 feet, which was characterized by organic soil with very loose silty sand with logs and roots and a high (II) erodibility according to HEC-18. Below ESU-2 at sites J-3 and J-4 was about 4 feet of ESU-3b, which was characterized by very dense sandy gravel with a medium (III) erodibility. The remaining depth of the J-3 and J-4 borings was ESU-4, which was characterized as fine-grained glacial deposits with stiff to hard silt to sandy silt with occasional gravel and has a high (II) erodibility. Boring site J-5 had ESU-3b for a depth of 3.5 feet and ESU-4 for the remaining depth. This geotechnical report also included a slope failure, described as a long cut slope failure, at MP 1.7 on SR 308 which is about a half mile from the project site. A minor slope failure, likely induced by a heavy rain event, was also reported at MP 2.16 on SR 308 which is about one mile from the project site.

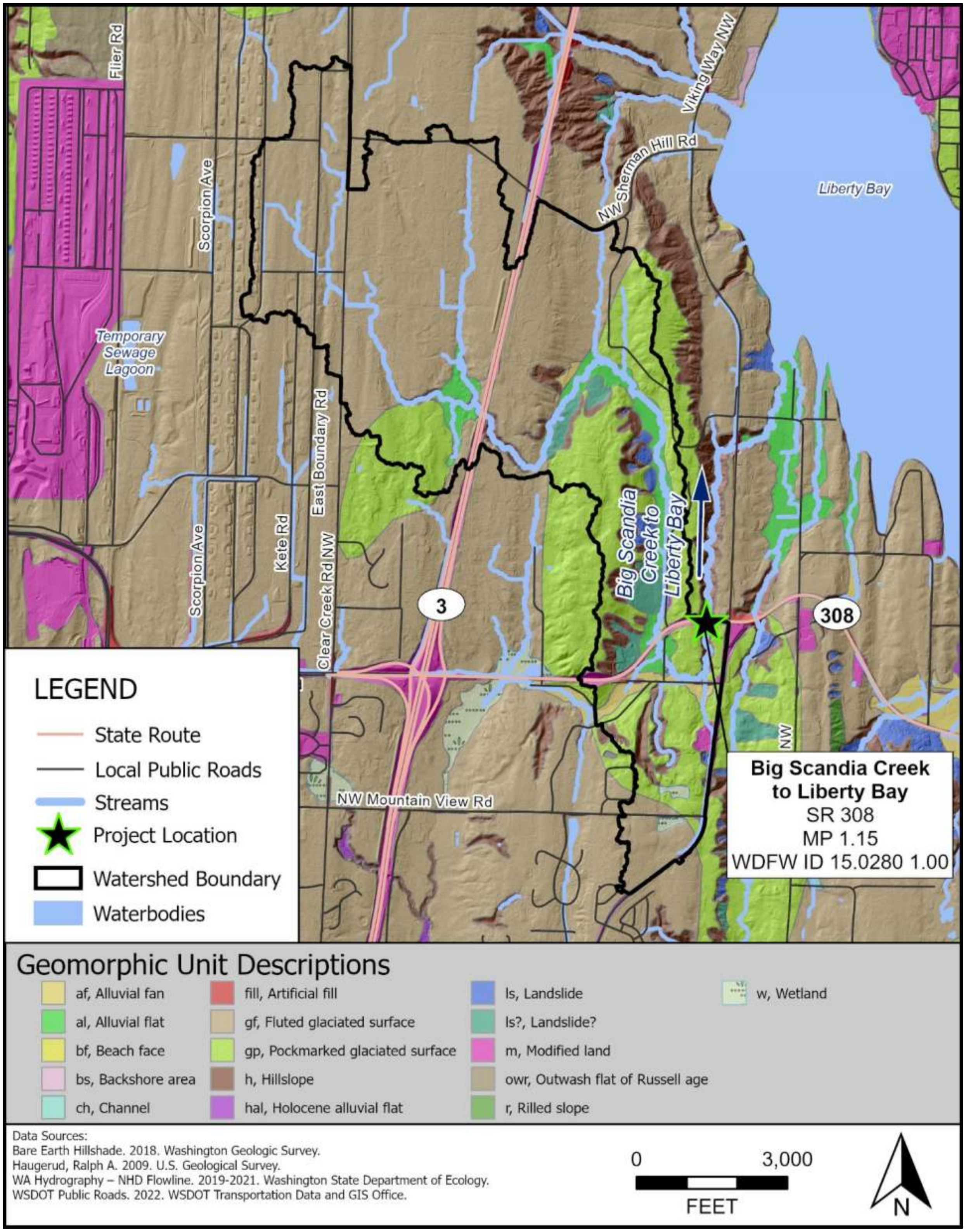

Figure 4: Geomorphic map

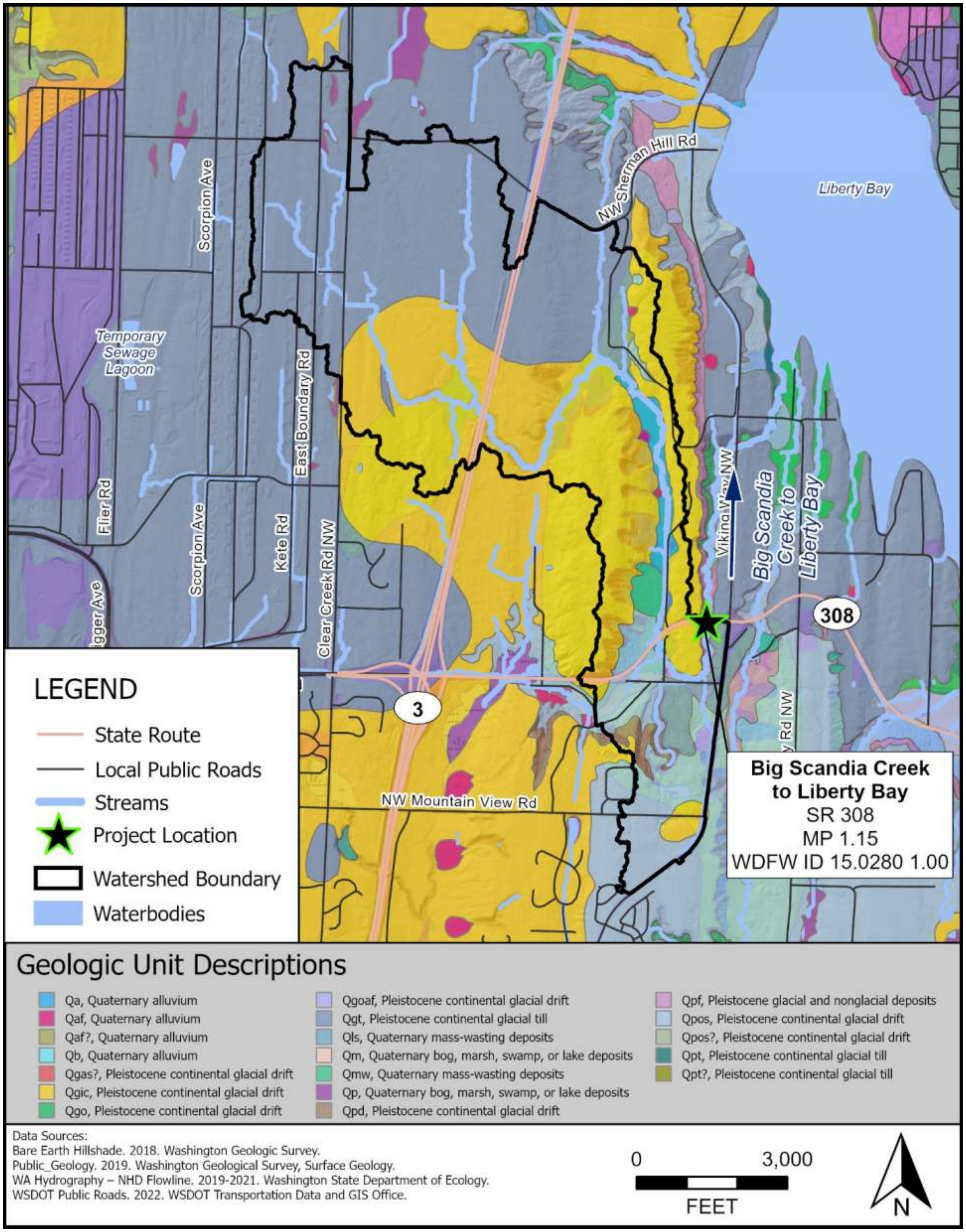

Figure 5: Geologic map

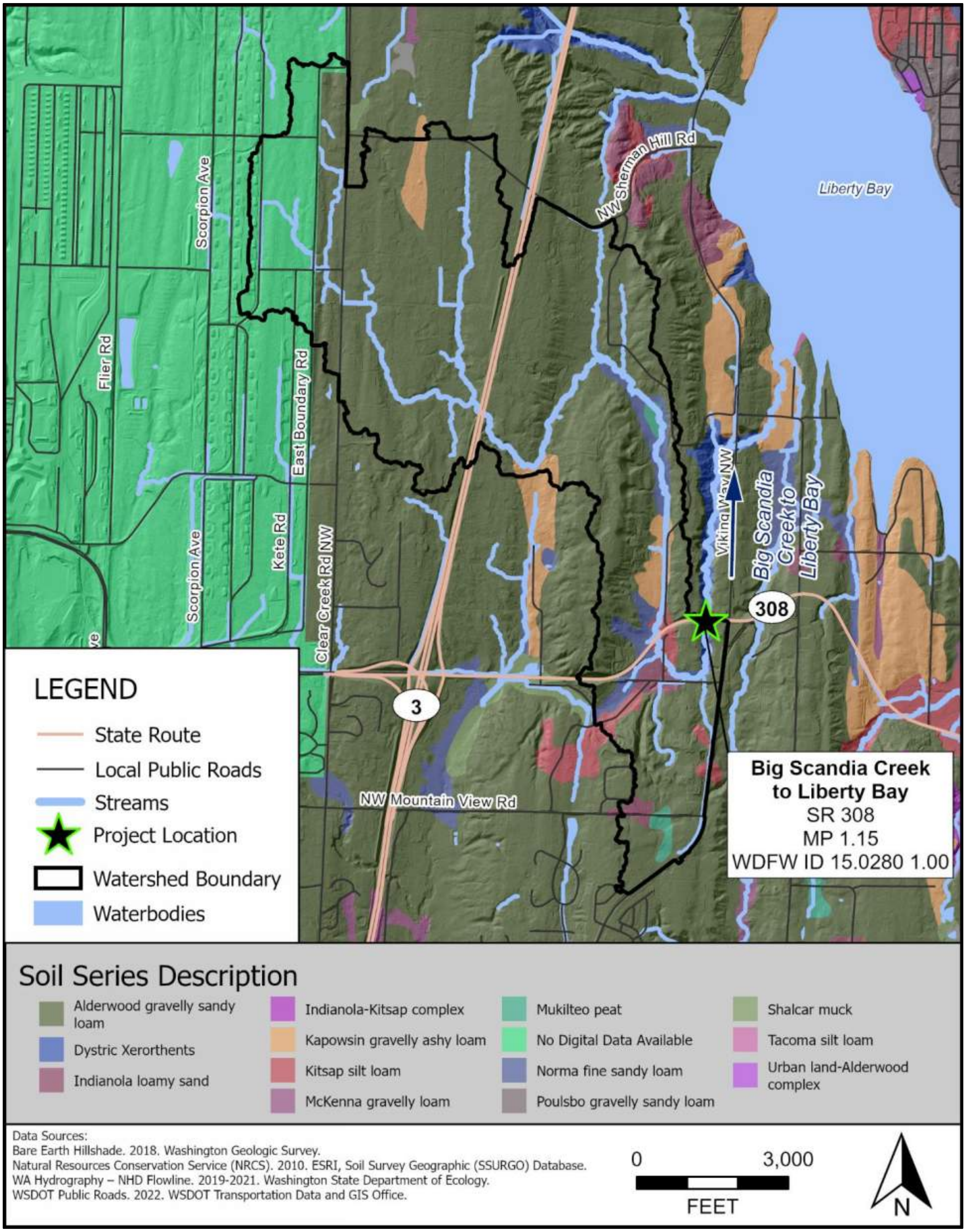

Figure 6: Soils map

2.4 Fish Presence in the Project Area

Table 2 provides a list of salmonid species documented, and presumed to be found in Big Scandia Creek, a tributary to Liberty Bay, Puget Sound. Documented salmonids in the stream are coho salmon (*Oncorhynchus kisutch*), fall chum salmon (*Oncorhynchus keta)*, winter steelhead (*Oncorhynchus mykiss*), and coastal cutthroat trout (*Oncorhynchus Clarki clarki*) (SWIFD 2021). Resident trout (*Oncorhynchus mykiss*) are presumed to be present. Information was gathered from the WDFW Fish Passage and Diversion Screening Inventory Database report (WDFW 2019) and the Statewide Washington Integrated Fish Distribution (SWIFD) dataset (WDFW 2021) managed by WDFW and the NW Indian Fisheries Commission.

Table 2: Native fish species potentially present within Big Scandia Creek

Species	Presence (presumed, modeled, or documented)	Data source	ESA listing
Coho Salmon (*Oncorhynchus kisutch*)	Documented	SWIFD	Not Listed
Fall Chum Salmon (*Oncorhynchus keta*)	Documented	SWIFD	Not Listed
Winter Steelhead (*Oncorhynchus mykiss*)	Documented	SWIFD	Not Listed
Coastal Cutthroat Trout (*Oncorhynchus Clarki clarki*)	Documented	SWIFD	Not Listed
Resident Trout (*Oncorhynchus mykiss*)	Presumed	SWIFD	Not Listed

2.5 Wildlife Connectivity

The 1-mile-long segment that Big Scandia Creek falls is unranked for Ecological Stewardship and medium priority for Wildlife-related Safety by WSDOT Headquarters (HQ) ESO. Adjacent segments to the west are ranked medium and to the south are ranked low for wildlife-related safety. A wildlife connectivity memorandum will not be provided at this site and additional width or height has not been recommended by WSDOT HQ ESO for wildlife connectivity purposes.

2.6 Site Assessment

2.6.1 Data Collection

David Evans and Associates, Inc. (DEA) visited the project site on November 29, 2021, to conduct a stream assessment and collect data to support preliminary design. The site visit occurred during winter baseflow conditions. Bankfull width (BFW) measurements and a pebble count were collected within the reference reach, a 160-foot segment of stream that begins approximately 175 feet upstream of the culvert inlet and extends to a point approximately 335 feet upstream of the culvert inlet (see Figure 7). The channel downstream of the culvert was not suitable for a reference reach because there was evidence of scour, bank erosion, and a section of nearly vertical clay bank downstream of the culvert.

DEA performed three pebble counts in the field—two upstream and one downstream of the crossing. The D_{84} and the D_{50} were determined to be 1.8 inches and 0.9 inches, respectively. Section 2.7.3 summarizes the results of the pebble counts. See the Hydraulic Field Report Form in Appendix B for a more thorough description of the November 29, 2021 site visit.

WSDOT and WDFW staff, along with Suquamish Tribal representatives (collectively referred to as “co-managers”) visited the site again on December 17, 2021. The purpose of this meeting was to establish concurrence on the BFW measurements used to inform the hydraulic opening width. DEA and the co-managers measured the BFW at six locations—four upstream and two downstream of the crossing. The co-managers requested removal of two the BFW measurements. Figure 7 shows a plan view of the site where these measurements were taken. The average BFW at the cross sections was 12.6 feet. The co-managers requested that the average BFW be rounded up to 13.0 feet (see Section 2.7.2). Section 2.6.2 includes further discussion on the results of this site visit.

In January 2022, WSDOT provided a topographic survey of Big Scandia Creek from approximately 200 feet downstream of SR 308 to approximately 300 feet upstream (see Appendix B). The survey included important features such as large woody material, significant trees, and infrastructure in the vicinity of the crossing.

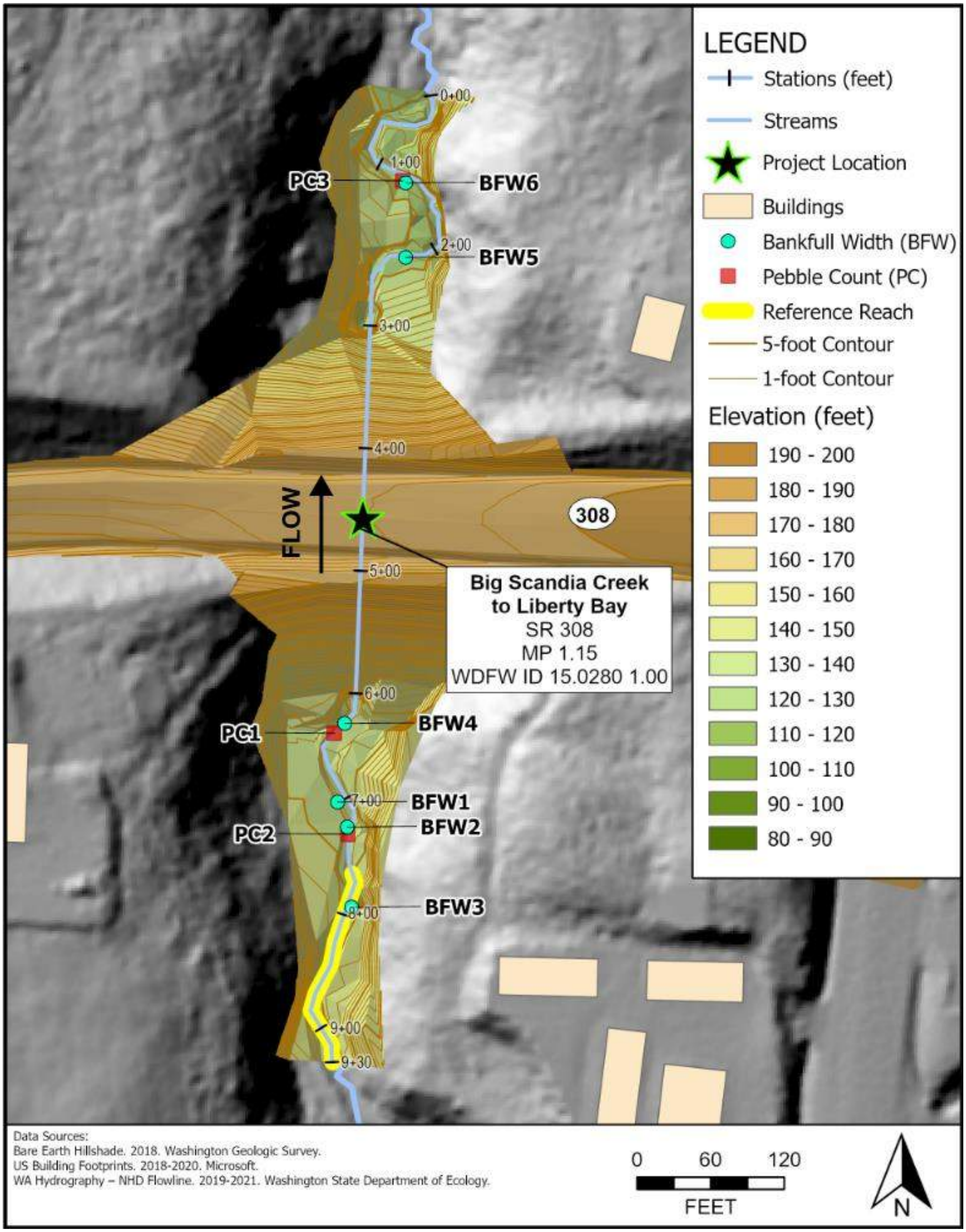

Figure 7: Reference reach, bankfull width, and pebble count locations

2.6.2 Existing Conditions

The site assessment began around station 9+35 (see Figure 7 for creek stationing) approximately 335 feet upstream of SR 308 in a confined valley with steep hillslopes on either side. A narrow alluvial flat makes up the overbanks of the channel. The channel is not incised, and the overbanks are readily accessible during flood flows. The channel exhibits some meandering but generally has low sinuosity upstream of the crossing (see Figure 8 and Figure 9). Channel slopes range from 1.0 percent to 2.0 percent in the observed upstream reach.

Figure 8 Characteristics of upstream reach (station 9+00)

Figure 9: Characteristics of upstream reach (station 7+60)

Within this stretch of the creek, some large woody material (LWM) and large boulders were observed within the channel. A long, 12-inch-diameter log was observed approximately 140 feet upstream of the culvert (station 7+40) (see Figure 10). A large boulder approximately 36 inches in diameter was observed within the center of the channel at approximately station 7+00 (see Figure 11). These features provide the majority of fish habitat within the upstream stretch of the creek and will primarily benefit adult salmonids in search of spawning gravels. Juvenile salmonids will find minimal rearing habitat in this straight shallow portion of the creek because of minimal flow obstructing features.

This section of channel between approximately station 7+75 and station 9+95 was relatively undisturbed by the structure influence of the crossing, and it provided the best location for a reference reach, even though some backwater reaches this location during large events such as the 100-year and 500-year events. The BFW was measured to be between 12 feet and 13 feet within the reach, and the reference reach has a slope of 1.5 percent. The bankfull depth was approximately 1.5 feet, and bed material was consistent with other portions of creek.

Figure 10: LWM in upstream reach (Station 7+40)

Figure 11: Rock in upstream reach (Station. 7+00)

A seasonal wetland was observed approximately 50 feet upstream of the culvert on the west overbank. The wetland was approximately 20 feet in diameter and had no obvious inlet or outlet (see Figure 12). There is a potential for fish stranding in this pool.

Figure 12: Wetland on the west bank, upstream of the culvert (station 6+50)

In the area just upstream of the crossing, a large cedar tree stump and gravel bar were observed at station 6+25. Gravelly material has accumulated in the bar, which is consistent with the bed material elsewhere in the channel (see Section 2.7.3). The base of the tree is within the creek channel and does provide areas of shelter during higher flows to juvenile salmonids (see Figure 13). A 12” CMP storm sewer pipe draining street runoff from SR 308 discharges into a ditch on the north side of the tree and enters Big Scandia Creek on the east bank (see Figure 14).

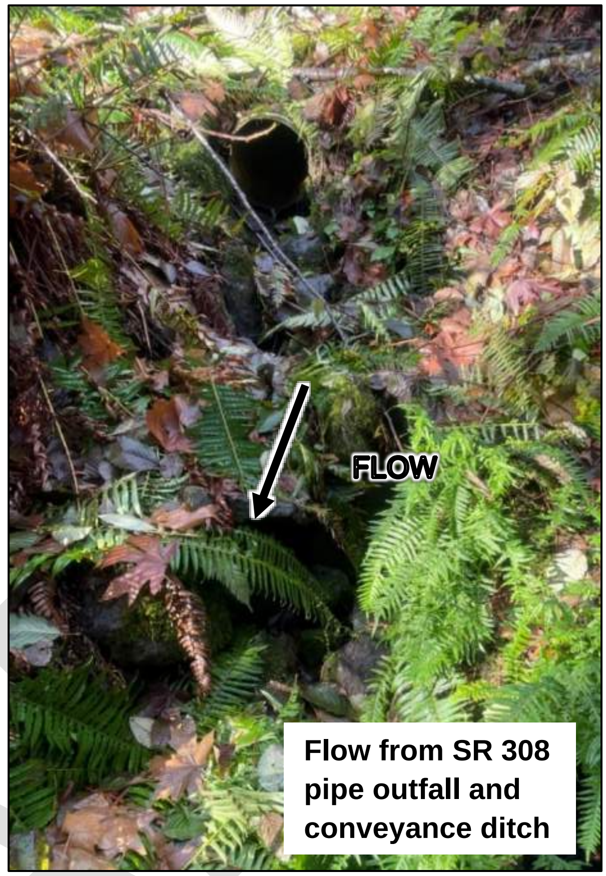

Figure 13: Looking upstream at sand bar and tree stump (station 6+25)

Figure 14: Looking at roadside pipe outfall (station 6+15)

As-built information provided by WSDOT for this section of SR 308 was reviewed, though no information pertaining to the crossing was available in these documents. The as-builts show that SR 308 was constructed in approximately 1945, and improvements occurred in the 1980s and 2000s. From survey information, this crossing consists of a 72-inch-diameter, 292-foot-long CMP culvert. The culvert inlet and outlet have metal flares as wingwalls to support transition of flow through the culvert. The culvert has a straight alignment through the highway fill. WDFW has identified this crossing as a fish barrier due to depth. The culvert was installed at a mild slope of 2.1 percent, as measured by survey data, and does not appear to significantly limit water or sediment capacity.

Visual inspection indicates that the culvert appears to be in relatively good condition. Minor rusting was observed along the bottom third of the culvert. Although there were no obvious signs of maintenance, the culvert inlet was clear of debris and blockage, with sand and pebble deposits directly upstream of the culvert. Figure 15 shows the culvert entrance, and Figure 16 shows inside the culvert. Immediately downstream of the outlet, the culvert outlet flows into a large scour pool approximately 30 feet wide by 25 feet long and approximately 3 feet deep, providing a larger than natural area for both juvenile and adult salmonids to find shelter. Bank erosion was observed east of the culvert exit (see Figure 17). The scour pool on the west side of the culvert appears to have been enlarged by a fallen tree and root system (see Figure 18).

Figure 15: Culvert inlet looking downstream (station 6+00)

Figure 16: Inside culvert looking downstream (station 5+90)

Figure 17: Culvert outlet looking upstream (station 3+00)

Figure 18: Culvert outlet looking upstream (station 3+00)

Water exits the scour pool through a relatively narrow section of channel (approximately 6 feet wide) that has an approximate 1-foot drop in elevation over 10 feet. A small plunge pool is located at the bottom (see Figure 19).

Figure 19: Scour pool exit, narrow channel, and plunge pool (station 2+30)

LWM was observed downstream of the plunge pool on the outside band at the location of channel meander. The collected material includes several channel-spanning logs of various sizes, including a large, 4-foot-diameter log, and provide abundant habitat for juvenile salmonids (see Figure 20).

Figure 20: Large woody material downstream of culvert (station 2+00)

The channel sinuosity and abundance of habitat features increases downstream of the crossing. The smallest meander radius is where the channel is laterally confined by a steep bank and hillslope of consolidated clay material (see Figure 21). The bank in this clay material is near vertical, and it extends up to approximately 5 feet above the water level. Pools that are approximately 2 feet deep are adjacent to the bank where the gravel bed material has washed through, indicating that scour is being directed downwards to the bed by the clay banks, which are resistant to erosion.

Figure 21: Clay bank looking downstream (station 1+80)

The channel continues to meander downstream of the clay bank. Channel slopes range from 1.0 percent to 2.0 percent in the observed downstream reach, accommodating to all fish species found within the stream. General channel and habitat characteristics downstream of the crossing are shown in Figure 22 and Figure 23, and include gravel bars to contribute spawning gravels, logs, tree stumps, and woody material near the channel for added rearing habitat. Several boulders and cobbles were observed within the downstream reach. The site evaluation ended at station 1+00, approximately 200 feet downstream of the crossing. No signs of maintenance activity were observed, and WSDOT maintenance records were unavailable to confirm during the assessment. Although not specifically observed, underground utilities are believed to be located in the crossing area. Pink flagging tape was observed along the creek, but the specific type of utility was not identified. The site visits included six BFW measurements taken (refer to Section 2.7.2) and three Wolman pebble counts (PCs) (refer to Section 2.7.3).

Figure 22: Characteristics of downstream reach (station 1+00)

Figure 23: Characteristics of downstream reach (station 1+10)

2.6.3 Fish Habitat Character and Quality

WDFW classifies the SR 308 culvert for Big Scandia Creek culvert as 67 percent passable because of depth (WDFW 2007). Site visits observed fish presence and use of the site, including documentation of adult coho. Other documented species in the creek are fall chum, winter steelhead, and coastal cutthroat trout, while resident trout are presumed to be within the creek. A DEA fish biologist visited the site to inform this report (see Section 2.6.1).

Conditions upstream of the culvert provide potential habitat for spawning, but minimal rearing habitat for juvenile salmonids. Vegetation provides the creek with only 50 percent stream cover, as the overstory and understory are not close enough to provide substantial shade and cover. The creek itself is slightly sinuous and features a relatively consistent pool-riffle complex, as seen in Figure 19; there are minimal pools and LWM to disrupt the flows of the creek, thus inhibiting the potential use for juvenile salmonids. Though this section is unlikely to be used by juvenile fish, the pool-riffle complex has resulted in a streambed composed of fine gravels, which support spawning activity. Farther upstream (approximately 200 feet), one LWM feature has created a scour pool, and a few large boulders have helped disrupt the flow. This area does provide potential habitat for rearing salmonids and areas to rest for fish migrating upstream. A wetland on the left bank of the river holds approximately 6 inches of standing water. The potential for salmonid spawning habitat here is good, because the substrate is composed of gravel with minimal sands and fine particulates throughout, and with faster, well oxygenated water. Rearing habitat in this section is limited, because minimal canopy cover, channel obstructions, and the lack of deeper pools present little refuge for rearing salmonids.

Downstream of the culvert there is a similar canopy cover of 50 percent to 60 percent. A wide channel is created from wood structures that obstruct the flow of the stream, creating many pools within the first few hundred feet of the culvert. These range in depth from 1.5 feet to 3 feet, and the largest is at the culvert discharge and is estimated to be 5 feet deep. The channel complexity provides great habitat for juvenile salmonids, and a large presence of snags in close proximity could contribute to more LWM in the future. Gravel and cobble are the most abundant throughout the streambed, though a large gravel bar on the right bank likely contributes fines to the system around 150 feet downstream of the culvert. Salmonid habitat in this section of the stream is good, because channel complexity and stream obstructions provide plenty of shelter for juvenile salmonids. Spawning habitat is also present here, given the adequate amounts of gravel and cobble, as well as channel obstruction to maintain oxygenated water. The one limiting factor here is canopy cover, which becomes sparse near the culvert, increasing the potential for stream warming and predation.

2.6.4 Riparian Conditions, Large Wood, and Other Habitat Features

Upstream of the culvert, the riparian area along the left and right banks of the creek consists of medium to large cedar and deciduous trees, and an understory of primarily salmonberry (*Rubus spectabilis*) and swordfern (*Polystichum munitum*). A wide floodplain results in minimal vegetation in proximity to the stream, providing sparse cover and shade to the stream, and limited LWM recruitment. There were LWM interactions during the winter baseflow conditions during the site visit, as seen in Figure 9 and Figure 10, but they were limited to single pieces or live trees or roots. The presence of large wood does create localized habitat and channel complexity, but long runs of more than 100 feet without wood also were observed that exhibited consistent pool-riffle morphology and had limited in-channel habitat features. The area immediately upstream of the crossing is consistently wet and is characterized by smaller brush-like material with minimal ferns (see Figure 12). The area immediately upstream and downstream of the crossing—approximately station 3+00 to station 6+00—was impacted by the construction of SR 308. Red alder (*alnus rubra*) and swordfern were present on the roadway embankments and indicate the area of disturbance.

Downstream of the culvert, the riparian area is primarily red alder, black cottonwood (*Populus trichocarpa*), Douglas-fir (*Pseudotsuga menziesii*), and western redcedar trees (*Thuja plilcata*), with a dense salmonberry understory. This salmonberry understory provides the stream with immediate cover, but acts as a buffer between the stream and forested area by creating an open canopy and as a barrier for significant LWM recruitment. Multiple snags are present on the site and could potentially be used for LWM recruitment in the future but should not be expected. One piece of LWM, shown in Figure 20, functions as a weir, providing habitat complexity to the stream. Another piece, shown in Figure 23, sits on the bank and would engage only in larger flood events. No noxious weeds were noted during the site investigations.

No indications of beaver presence or activity were observed upstream or downstream of the crossing, and the presence of beavers is not expected in the future.

2.7 Geomorphology

Geomorphic information provided for this site includes selection of a reference reach, the geometry and cross sections of the channel, and stability of the channel both vertically and laterally of Big Scandia Creek.

2.7.1 Reference Reach Selection

The reference reach is a 220-foot segment of stream that begins approximately 175 feet upstream of the culvert inlet, extending to a distance approximately 395 feet upstream of the culvert inlet (see Figure 7). There was no evidence of scour and minor deposition at the upstream end of the culvert, indicating that the culvert is not capacity limited at most flood events, and the culvert causes little upstream hydraulic influence. There are no human-made features close to the reference reach, indicating that it represents an undisturbed condition for Big Scandia Creek. The reference reach has consistent gravel bed material and slight meandering through a narrow floodplain confined by steep hillslopes (see Figure 8 and Figure 9). The overbanks are readily accessible during flood events, although floodplain limits were not observed. The reference reach has low-amplitude riffle features without significant pools; the riffles transition directly into run features. There is infrequent wood material in the channel near the banks. The site visit noted one piece of large wood material oriented across the flow that resulted in a local scour pool that was 1.7 feet deep (see Figure 24).

The channel immediately downstream of the culvert was not suitable for a reference reach because of evidence of scour and bank erosion directly downstream of the culvert for about 30 feet (see Figure 17). The channel appears to take a more natural form farther downstream. A natural clay hillslope restricts the channel approximately 160 feet downstream of the channel (see Figure 21).

Figure 24: In-channel large wood material that has created a scour pool 1.7 feet deep

Survey of the reference reach indicates that the channel slope here is approximately 1.5 percent. Conditions in the reach were characterized by a BFW measurement, which was combined with three other BFW measurements from outside the reference reach to establish an average BFW (see Section 2.7.2) of 12.6 feet for the channel through the project area. As discussed in Section 2.7.2, the design BFW was increased to 13.0 feet after discussion with the co-managers. One pebble count was taken just downstream of the reference reach, and two additional pebble counts were taken further downstream from the reference reach (as discussed in Section 2.7.3) to measure the sediment distribution. The full channel length through the project area has similar characteristics including the reference reach, so data collection was not limited only within the reference reach.

During a site visit on December 17, 2021, WDFW and project co-managers concurred with the location of the reference reach.

2.7.2 Channel Geometry

The channel is wide and shallow and has BFWs ranging from 12 feet to 13 feet. Six BFWs were measured, one of which was within the reference reach. Only one BFW measurement was taken in the references because there was evidence of backwatering in the reach. So, only one location was deemed appropriate for a measurement. Two of the six BFW measurements were rejected by the co-managers and therefore were not included in the average BFW. The remaining four BFWs were used in establishing the design average width (see Figure 25, Figure 26, Figure 27, and Figure 28). The bankfull elevation was identified by an inflection point in the slope or where vegetation was not present. This point was generally 1 foot higher than the wetted depth at the time of the site visit, during which the water depth was approximately 3 inches to 9 inches. As seen in the figures, the water depths were lower than the depths for bankfull events. The average slope of the stream (1.5 percent) was consistent within and outside of the reference reach at the selected BWF measurements.

The stream appears to be stable in nature because the banks have developed without any clear indications of erosion. However, fallen and tilting trees observed along the stream banks indicate some lateral migration. The channel is estimated to be in Stage IV—quasi equilibrium—according to the stream evolution model depicted in the document *Providing Aquatic Organism Passage in Vertically Unstable Streams* (Castro and Beavers 2016). With the scour pool at the downstream end of the culvert, the downstream section has shallower channel depth and seems to have a wider floodplain than the upstream section (see Section 2.7.2.1).

Bankfull depths were not provided in the site visit notes, but Figure 29 indicates the average bankfull depth upstream of the crossing is 1.4 feet. With an average BFW upstream of 12.5 feet, the width-to-depth ratio is 8.9. Downstream of the crossing, the bankfull depth indicated in Figure 29 is 0.7 feet. With a BFW of 13 feet in this location, the width-to-depth ratio downstream of the cross is 18.9. This significant difference illustrates the transition from a confined system upstream of the crossing to an unconfined system downstream of the crossing, as discussed in Section 2.7.2.1. The width-to-depth ratio is an indicator of habitat quality: relatively deep, narrow streams provide better fish habitat than shallow, and wider channels.

Figure 25: BFW-1 measurement of 12.5 feet measured downstream of the reference reach, approximately 118 feet upstream of the culvert

Figure 26: BFW-2 measurement of 13 feet measured downstream of the reference reach, approximately 140 feet upstream of the culvert

Figure 27: BFW-3 measurement of 12 feet measured within the reference reach, approximately 175 feet upstream of the culvert

Figure 28: BFW-6 measurement of 13 feet measured downstream of the reference reach, approximately 160 feet downstream of the culvert

Table 3 summarizes the BFW measurements. The BFW measurements used in characterizing the stream based on co-manager concurrence range from 12.0 feet to 13.0 feet both within and outside the reference reach. Figure 29 shows a comparison of channel geometry for the locations where BFWs were measured and approved by the co-managers. The project team discussed the measured BFWs and hydraulic opening with WDFW staff and co-managers during the site visit on December 17, 2021. The co-managers did not concur with two of the initial BFW measurements and added an additional BFW measurement beyond the reference reach (BFW-6) for inclusion in the BFW average (see Figure 7 in Section 2.6.1 for a map showing BFW measurement locations). The inclusion of this new BFW measurement increased the average BFW to 12.6 feet. However, during the site visit, the co-managers preferred an average BFW of 13.0 feet. This agreed-upon BFW will be used to inform the width of the structure opening based on the unconfined bridge method.

Table 3: Bankfull width measurements

BFW number	Width (ft)	Included in design average?	Location measured (station)	Concurrence notes
BFW-1	12.5	Yes	Sta. 6+96	Stakeholder concurred on 12/17/2021
BFW-2	13	Yes	Sta. 7+28	Stakeholder concurred on 12/17/2021
BFW-3	12	Yes	Sta. 7+75	Stakeholder concurred on 12/17/2021
BFW-4	10	No	Sta. 6+13	Stakeholder removed 12/17/2021
BFW-5	22	No	Sta. 2+23	Stakeholder removed 12/17/2021
BFW-6	13	Yes	Sta. 1+13	Stakeholder added on 12/17/2021
Design Average	12.6	-	-	Design BFW of 13.0 ft agreed upon on 12/17/2021

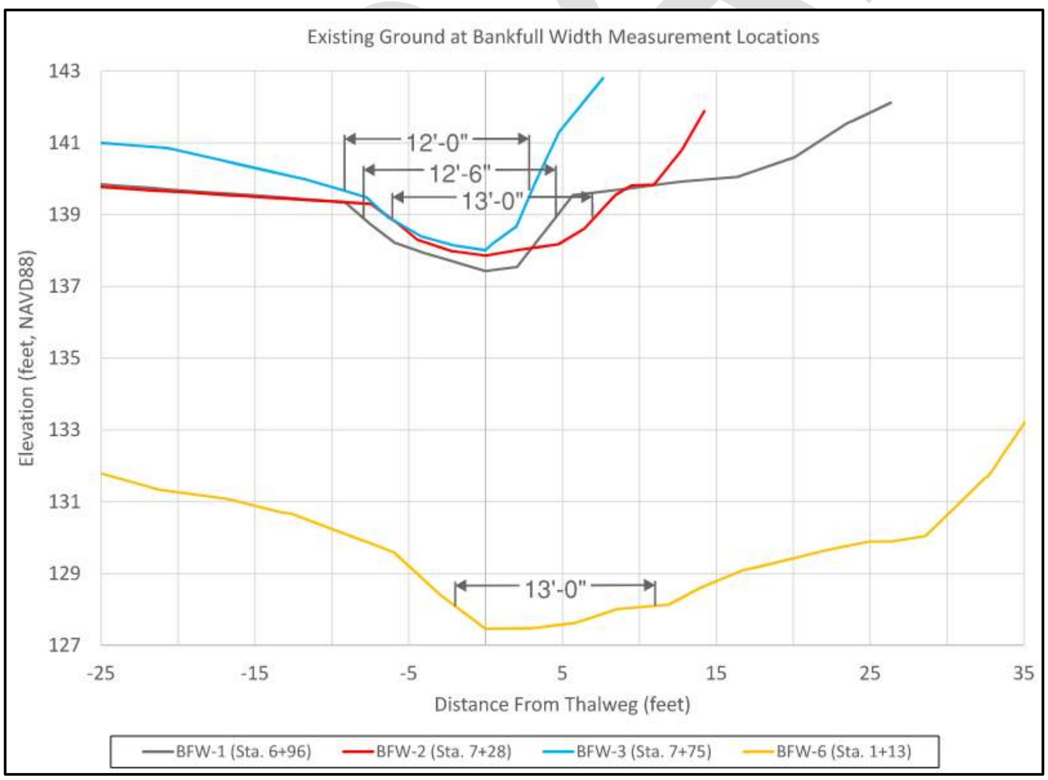

Figure 29: Existing cross-section at four BFW locations

2.7.2.1 Floodplain Utilization Ratio

The floodplain utilization ratio (FUR) is an indication of channel entrenchment and is a ratio of the flood-prone width (FPW) to the bankfull width. The FPW is the water surface width at twice the bankfull depth, or the width at the 50-year to 100-year flood. A FUR of less than 3.0 is considered a confined channel, and a FUR greater than 3.0 is considered an unconfined channel. The FUR can be determined through field measurements or hydraulic modeling. For this project, the FUR was measured from hydraulic model results of the existing 100-year peak flow and the average BFW measured in the field, where available, and the 2-year flood extents elsewhere.

The project team determined the FPW of Big Scandia Creek by measuring the 100-year flood width from the natural conditions hydraulic model at various representative locations upstream and downstream of the crossing. Figure 30 shows the location of each FPW measurement, and Table 4 provides the FPW measurement values. The upstream FPW measurements were taken in the natural conditions model to avoid the backwater conditions of the existing crossing. The FUR varies from 2.0 to 4.4; the average of the upstream FURs, including stations 9+93 and 11+43, which are not included in the overall average but are included in the upstream average to highlight the confined nature of the upstream reach, is 2.8. The average of the downstream FURs is 3.7. Upstream of the reference reach, where the first two FUR measurements shown in Table 4 were taken, the stream is confined. In the reference reach, where measurements at stations 7+75 and 8+27 were taken, the stream is unconfined with a FUR larger than 3.0. Downstream of the crossing, the stream is unconfined. Thus, the reference reach marks the transition from confined to unconfined flow in this channel. After discussions with the co-managers, it was decided to treat the SR 308 crossing as unconfined as it is just downstream of a transition from confined to unconfined flow.

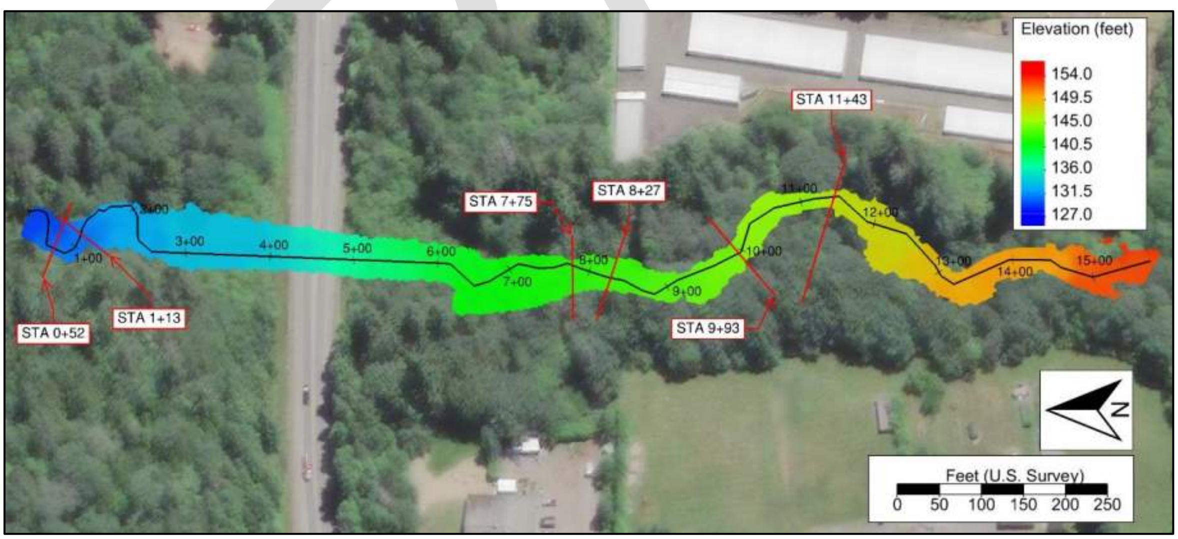

Figure 30: FUR locations

Table 4: FUR determination

Station	FPW (feet)	Measured BFW (feet)	2-year flood extents (feet)	FUR	Confined or unconfined	Included in average FUR determination
US 11+43	21.1	N/A	10.6	2.0	Confined	No
US 9+93	28.1	N/A	13.6	2.1	Confined	No
US 8+27	40.4	N/A	11.2	3.6	Unconfined	Yes
US 7+75	41.2	12.0	11.9	3.4	Unconfined	Yes
DS 1+13	56.9	13.0	15.4	4.4	Unconfined	Yes
DS 0+52	41.5	N/A	14.0	3.0	Unconfined	Yes
Average	45.0	-	-	3.6	Unconfined	-

2.7.3 Sediment

DEA conducted three Wolman pebble counts at the site: one just outside of the reference reach, two farther downstream. See Figure 7 for pebble count locations. A pebble count was not conducted in the reference reach because the sediment sizing was observed to be consistent throughout the stream, as seen in Table 5, so it was decided that an additional count was not necessary. The channel bed consists of sand, coarse gravel, and cobbles. In addition, the majority of the creek water was observed to have low turbidity. The banks consist of cohesive soils and are well vegetated upstream of the crossing within the reference reach. The channel downstream of the reference reach has steep exposed banks of cohesive material. During the site visits, evidence of channel widening, or lateral erosion, was limited to a location in the downstream reach where a large stump had created a flow obstruction (see Figure 20). The channel and bank did not appear to be actively eroding, other than at the downstream scour pool. An armoring layer was not observed.

Several large boulders, approximately 12 inches to 36 inches, were observed within and near the channel (see Figure 11, Figure 20, Figure 31, and Figure 32).

Figure 31: Boulder in stream (station 1+13)

Figure 32: Boulders in stream (1+50)

PC-1 was conducted along a length of stream approximately 50 feet upstream of the existing culvert. The sediment here consisted of coarse sands, gravels, and small cobbles 3.5 inches or less. See Figure 33 and Figure 34 for approximate sediment dimensions and distributions at the location of PC-1.

Figure 33: PC-1 sediment with gravelometer

Figure 34: PC-1 sediment in hand

PC-2 was conducted along a length of stream approximately 140 feet upstream of the existing culvert inlet. The sediment here consisted of coarse sands, gravels, and small cobbles 3.5 inches or less. This pebble count, just downstream of the reference reach, was taken over a distance of about 50 feet that exhibited faster flow and few fines; therefore, this pebble count represents the upper size limit of coarse material that could be mobilized by the stream without the influence of wood material or other potential grade controls. In slackwater areas such as pools, this material will become overtopped with sand, as was observed locally within the reach. See Figure 35 and Figure 36 for approximate sediment dimensions and distributions at the location of PC-2.

Figure 35. PC-2 sediment with gravelometer

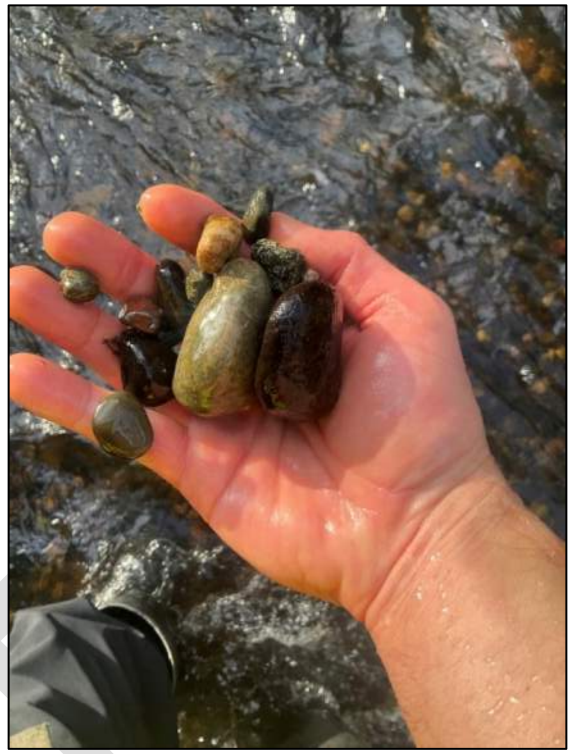

Figure 36: PC-2 sediment in hand

PC-3 was conducted along a length of stream approximately 125 feet downstream of the culvert outlet. The sediment here consisted of coarse sands, gravels, and cobbles 7.1 inches or less. See Figure 37 and Figure 38 for approximate sediment dimensions and distributions at the location of PC-3.

Figure 37: PC-3 sediment with gravelometer

Figure 38: PC-3 sediment in hand

Table 5 and Figure 39 show the sediment distribution results for the pebble counts.

Table 5: Sediment properties near the project crossing

Particle size	Pebble Count 1 (PC-1) diameter (in)	Pebble Count 2 (PC-2) diameter (in)	Pebble Count 3 (PC-3) diameter (in)	Average diameter for design (in)
Included in average?	Yes	Yes	Yes	
D_{16}	0.4	0.5	0.3	0.4
D_{50}	0.8	1.0	1.0	0.9
D_{84}	1.8	1.9	1.8	1.8
D_{95}	2.4	2.5	2.3	2.4
D_{100}	3.5	3.5	7.1	4.7

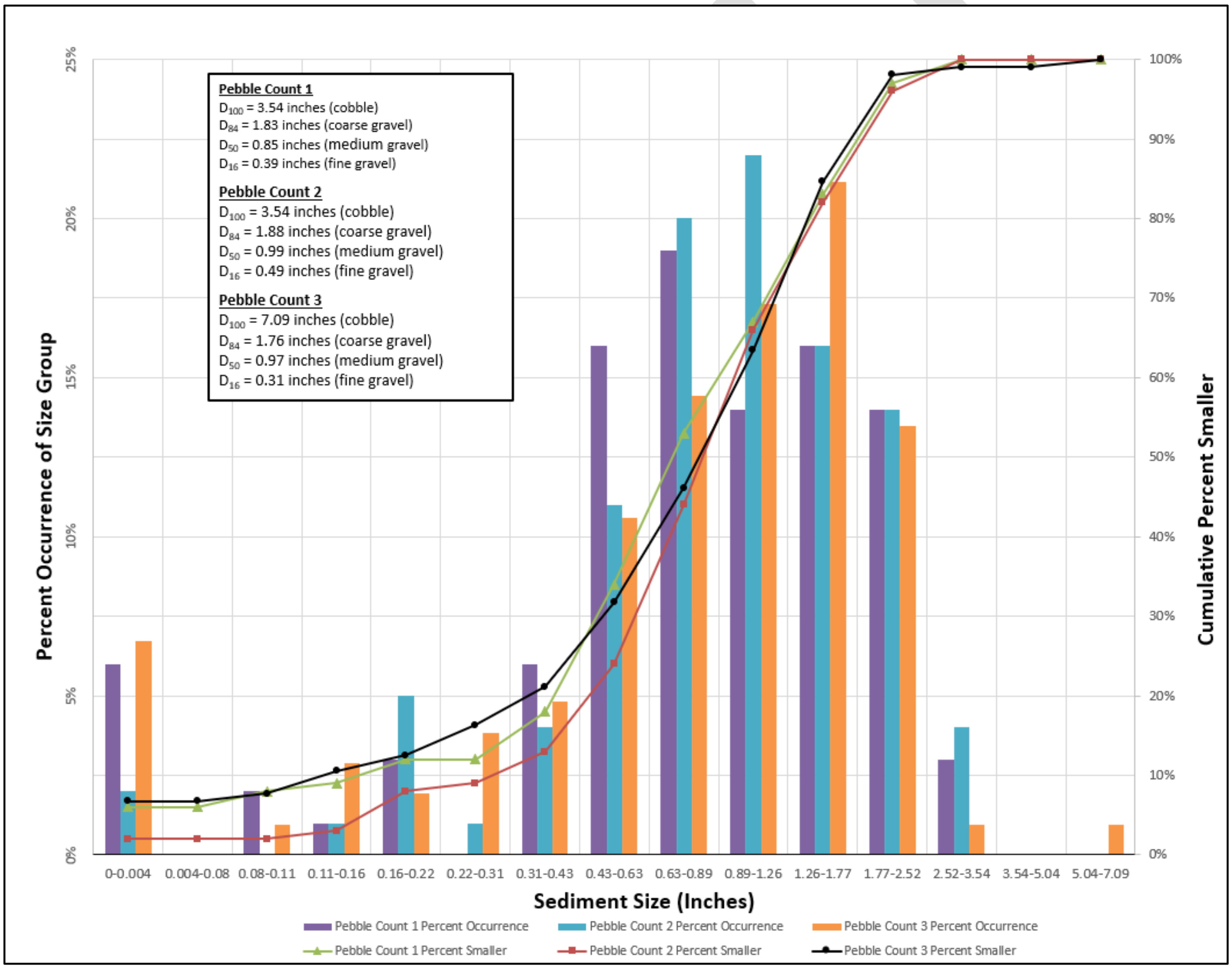

Figure 39: Sediment size distribution

2.7.4 Vertical Channel Stability

The channel bed is dominated by coarse material ranging from fine gravels to cobbles. These materials create a low-amplitude pool-riffle sequence where the flow over the riffles is less than 6 inches deep and the flow through the pools is less than 12 inches deep. Because of the shallow pools, the bed material is relatively consistent throughout the reach and there is minimal channel complexity. There is no evidence of recent erosion in the form of downcutting or lateral migration, indicating that the channel is vertically and laterally stable and has simple geometry. There are no significant hard points along the channel that result in grade control other than the SR 308 crossing itself. There are locations that are influenced by single pieces of large wood or trees (see Figure 13 and Figure 24) that have locally created greater channel complexity in the form of deeper pools, sand deposition, and bank undercutting. There was one large wood complex consisting of multiple pieces of wood material downstream of the culvert outlet (see Figure 20). Increasing the amount of wood material in the channel would improve habitat but is not necessary for channel stability.

The upstream and downstream portions of Big Scandia Creek appear to have ample sediment supply because no active vertical incision was observed upstream of the culvert. The channel appears to be in Stage IV—quasi equilibrium—according to the stream evolution model depicted in the document *Providing Aquatic Organism Passage in Vertically Unstable Streams* (Castro and Beavers 2016).

Figure 40 shows what the expected equilibrium of this channel might be like when the SR 308 culvert is removed. The unobstructed channel gradient is expected to be close to 1.6 percent. When the SR 308 culvert is replaced and the channel restored, approximately 0.8 feet natural degradation may occur slowly over time upstream of the new crossing, as seen in Figure 71. Aggradation of this channel is not anticipated because of the consistent channel slope upstream and downstream of the crossing. See Section 7.2 for additional discussion of potential degradation.

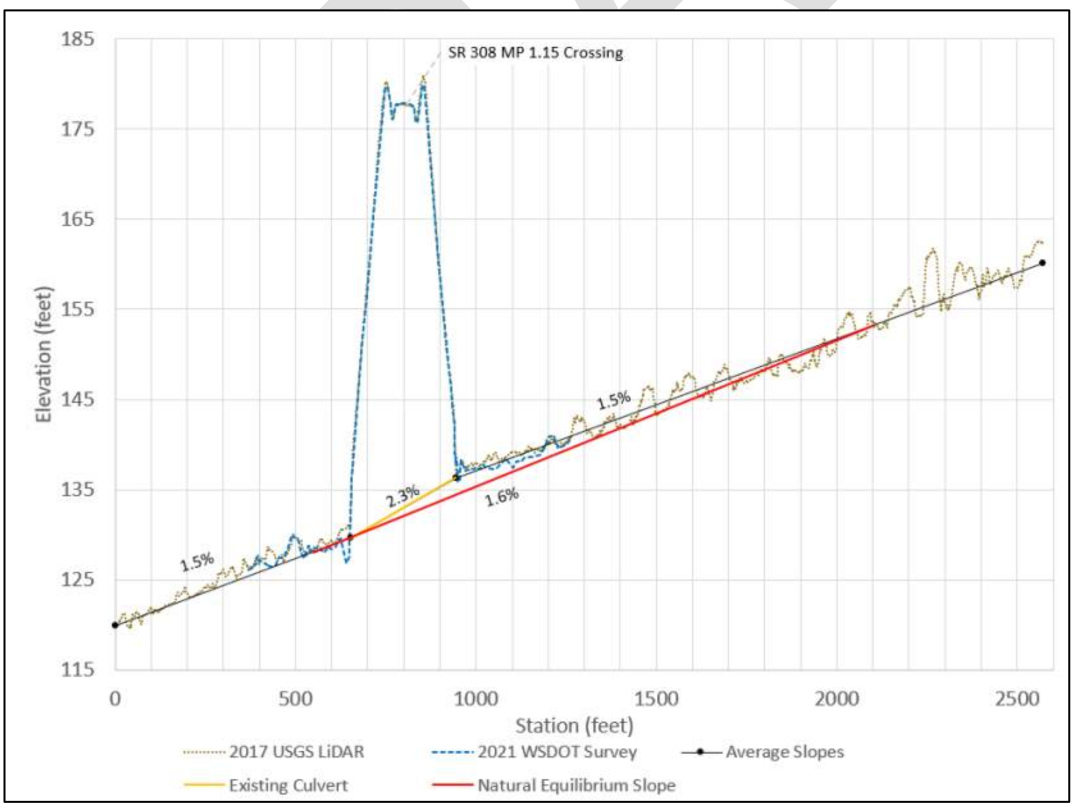

Figure 40: Watershed scale longitudinal profile

2.7.5 Channel Migration

The site visits revealed no evidence of recent lateral erosion or migration nor did the site visits or LiDAR topography show any longer-term channel migration. The channel is in a confined valley with steep hillslopes on either side. Near the culvert there is a narrow alluvial flat that makes up the overbanks of the channel. This narrow overbank area acts as the floodplain for the stream. This narrow alluvial flat continues downstream of the culvert and widens. The presence of the alluvial flat/overbank feature indicates that the channel had migrated between the valley hillslopes; however, there was no evidence of historical channel depressions, nor were they observed in the field or in the LiDAR. The channel exhibits some meandering but generally has low sinuosity. The smallest meander radius is downstream of the culvert, where the channel is laterally confined by a steep bank and hillslope of consolidated clay material (see Figure 41). The bank of this clay material is nearly vertical and extends up to approximately 5 feet above the water level. Dense clay materials are erosion-resistant but may deteriorate slowly through abrasion as gravels transport through the reach. There are pools approximately 2 feet deep adjacent to the bank where the gravel bed material has washed through, indicating that scour is being directed downwards to the bed by the clay banks that are resistant to erosion.

Figure 41: Steep clay bank where the channel is adjacent to the valley hillslope

3 Hydrology and Peak Flow Estimates

The mean annual precipitation predicted for the watershed is 42.5 inches (PRISM Climate Group 2021), and the drainage area is 2.1 square mile. See Section 2.2 for discussion of the watershed delineation and other basin characteristics.

Peak flows were estimated using MGS Flood (MGS 2021) and the USGS Regression Equations for Region 3 (Mastin et al. 2016). The WSDOT Hydraulics Manual specifies both MGS Flood and the USGS Regression Equations as acceptable hydrologic methods for ungaged locations (WSDOT 2022a). MGS Flood contains extended timeseries for most of western Washington. The extended precipitation timeseries are applicable to sites with mean annual precipitation between 24 and 80 inches. Since the mean annual precipitation (MAP) is 42.5 inches, peak flows were evaluated at regular return intervals using two peak flow estimation methods: the USGS Region 3 regression equations (USGS 2016) and MGSFlood software for the GIS delineated basin. The amount of impervious area used in the MGS Flood model is approximately 3.9 percent. Table 6 shows the peak flows estimated by all the methods previously mentioned.

Generally, in the absence of calibration data, hydraulic models are calibrated so that the 2-year flow depth is roughly equivalent to the BFW within a given stream. Hydraulic modeling with the regression equations estimates of the mean peak flows generally filled the bankfull channel (i.e., the modeled 2-year water surface extents were comparable to the measured BFWs), and the 2-year flow depth is roughly equivalent to the bankfull depth. However, for the flows other than 2-year (i.e., 5-year, 10-year, 25-year, 50-year, 100-year, 500-year), MGS Flood flow results are larger than USGS regression equation flow results for different MRIs. And the bankfull width and depth calculated from 2-year flow of MGSFlood varies within 5 percent of bankfull width and depth calculated from 2-year flow of USGS regression equation. Because MGSFlood results in larger flows for the other MRIs, utilizing them will result in a more conservative final design. Larger flows result in higher minimum low chords and typically result in larger scour, making the final design more resilient.

There are no stream gages on Big Scandia. There is, however, a gage in the nearby Clear Creek. This creek has a basin size of 3.25 square miles, as delineated by StreamStats, and is therefore approximately 1.5 times larger than the Big Scandia basin at the 15.0280 1.00 site. Both creeks have similar mean annual precipitation (43.8 inches at Clear Creek and 42.5 inches at Big Scandia). The Clear Creek stream gage data begins in 2001 and continues through 2022. However, there is a gap in the data from 2003 to 2012. So, 14 years of discontinuous hourly gage data was available for frequency analysis. No quality control documentation was available for the dataset, so it was used in “as-is” condition. The Bulletin 17C procedure was used in HEC-SSP version 2.2 to estimate flood quantiles with weighted skew.

For comparison of peak flows between the two sites, the median estimate of both 100-year Clear Creek peak flow and 100-year MGSFlood Big Scandia Creek peak flow were normalized by drainage area, resulting in a unit discharge per unit area, i.e. cfs per square mile. The difference in normalized peak flow between the two sites was calculated as 20 percent. This difference of 20% is still within the confidence intervals of both datasets. Other factors which may contribute to a discrepancy between the two normalized flow values include the shape of the watershed, slope of the watershed, land use, and length of longest flow path (time of concentration) among others. So, based upon the results of this analysis, the design team concluded that the flow estimates of Big Scandia Creek from MGSFlood are in agreement with regional hydrology as estimated using the gage data from Clear Creek.

Additionally, two PHDs completed for sites upstream of this crossing utilized MGSFlood flows. These sites (IDs 996804 and 990235) have basin areas of 0.97 square miles and 1.8 square miles respectively. These basins drain into the Big Scandia (ID 15.0280 1.00) basin, and so the flows should be larger at this crossing than the two upstream sites. The MGSFlood results for all three sites have been compared and do show that the downstream sites have larger flows than the upstream sites. If the USGS flows were used at this site, the logic of having larger flows further downstream would be broken and there would not be consistency in the design at the three sites. Therefore, to be conservative and to maintain consistency with other fish passage projects on the same stream, MGSFlood values were used for the design.

It is assumed that peak flows from Big Scandia Creek's basin are the only flows affecting the crossing at Site 15.0280 1.00. No other sources of significant flow, including the 100-year flood (see Section 6), encroach upon the SR 308 roadway at this location.

WSDOT recognizes climate resilience as a component of the integrity of its structures and approaches the design of bridges and buried structures through a risk-based assessment beyond the design criteria. The largest risk to bridges and buried structures will come from increases in flow and/or sea level rise. The goal of fish passage projects is to maintain natural channel processes through the life of the structure and to maintain passability for all expected life stages and species in a system.

WSDOT evaluates crossings using the mean percent change in 100-year flood flows from the WDFW Future Projections for Climate-Adapted Culvert Design program. All sites consider the projected 2080 percent increase throughout the design of the structure. Appendix G contains the projected increase information for the project site. The design flow for the crossing is 247.6 cubic feet per second (cfs) at the 100-year storm event. The projected increase for the 2080 100-year flow in the adjacent watershed is 62.2 percent, yielding a projected 2080 100-year flow of 401.6 cfs.

Table 6: Peak flows for Big Scandia Creek at SR 308

Mean recurrence interval (MRI) (years)	MGSFlood (cfs)	USGS Regression (Region 3) (cfs)
2	**39.3**	45.8
10	**113.5**	90.9
25	**167.4**	115.0
50	**215.5**	133.0
100	**247.6**	152.0
500	**297.1**	198.0
Projected 2080 100	**401.6**	246.5

4 Water Crossing Design

This section describes the water crossing design developed for SR 308 MP 1.15 Big Scandia Creek, including channel design, minimum hydraulic opening, and streambed design.

4.1 Channel Design

This section describes the channel design developed for Big Scandia Creek at SR 308 MP 1.15.

4.1.1 Channel Planform and Shape

The WCDG (Barnard et al. 2013) recommends that a proposed stream channel have a gradient, cross section, and general configuration that is similar to the existing channel upstream and downstream of the proposed crossing, provided that the adjacent channel has not been modified in a way that adversely affects natural stream processes. The stream assessment evaluated existing conditions for Big Scandia Creek upstream and downstream of the SR 308 crossing.

Much of the channel hydraulic properties, such as flow depth, velocities, and sediment transport, depend on the shape of the channel cross section. Therefore, the proposed channel shape is designed to mimic the existing sections observed in the reference reach and measured from survey data. Figure 43 shows a typical section of the proposed channel geometry and compares it to cross sections of the proposed channel geometry, both upstream and downstream of the SR 308 crossing as well as within the reference reach. Observed channel banks at the project site were relatively stable and did not have much aggradation or degradation at the reference reach, so these bank slopes were used to determine the proposed channel cross section bank slopes. Mimicking the existing channel shape in determining the proposed design will support creation of flow regimes at the proposed section that will continue the same channel processes seen in the reference reach and through the crossing. The cross-slope of the proposed channel bed was also estimated using the reference reach channel shape to ensure that sediment transport remains steady and representative of the existing reference reach. Using the channel shape of the reference reach to estimate the proposed channel bed cross-slope also ensures that the proposed channel section will not have long-term degradation or aggradation of sediments on the bed. Designing the proposed channel section based on bank heights and widths from the reference reach means that flow depths and velocities for fish passage and habitat will be close to natural conditions during low or high flows. A channel that is too wide can result in lower flow depth during low-flow periods, and narrow sections can result in higher velocities than those of the natural conditions of the channel, which would in turn adversely affect fish passage and habitat. The channel is intended to provide adequate depth and flow velocities, so that salmonids can use it across all their life stages.

The proposed channel width is 13 feet and consists of a 5-foot channel bottom with 3:1 bank slopes that extend 4 horizontal feet on each side of the channel bottom. Floodplain benches are present on both sides of the channel (at 10:1 grade) before the typical cross section resumes the 2:1 grade to tie into the existing ground. The proposed channel 3:1 side slopes are 1.3 feet deep, with another 0.3 feet depth within the 10:1 channel bottom. The total channel depth is 1.6 feet. See Figure 42.

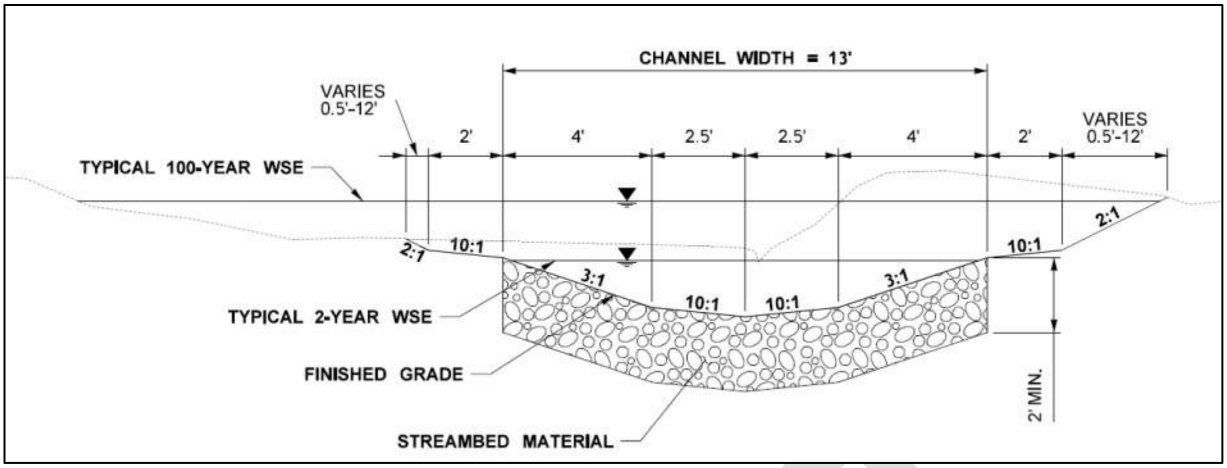

Figure 42: Design cross section

The modeled 2-year water surface width in the proposed conditions is approximately 12.8 feet throughout the crossing and in adjacent sections of stream, which is expected, as the BFW measurements that were taken varied from 12.0 feet to 13.0 feet. In later stages of the project, a low-flow channel will be added that connects habitat features together so that the project is not a low-flow barrier. The low-flow channel will be as directed by the engineer in the field.

Over time, the channel is expected to self-adjust and benches are expected to extend upstream and downstream of the crossing to closer match the proposed 30-foot minimum hydraulic opening. The proposed grading upstream and downstream of the crossing does not include these benches in order to preserve existing trees and vegetation. The widening of the benches will not cause channel instability or pose a risk to the structure.

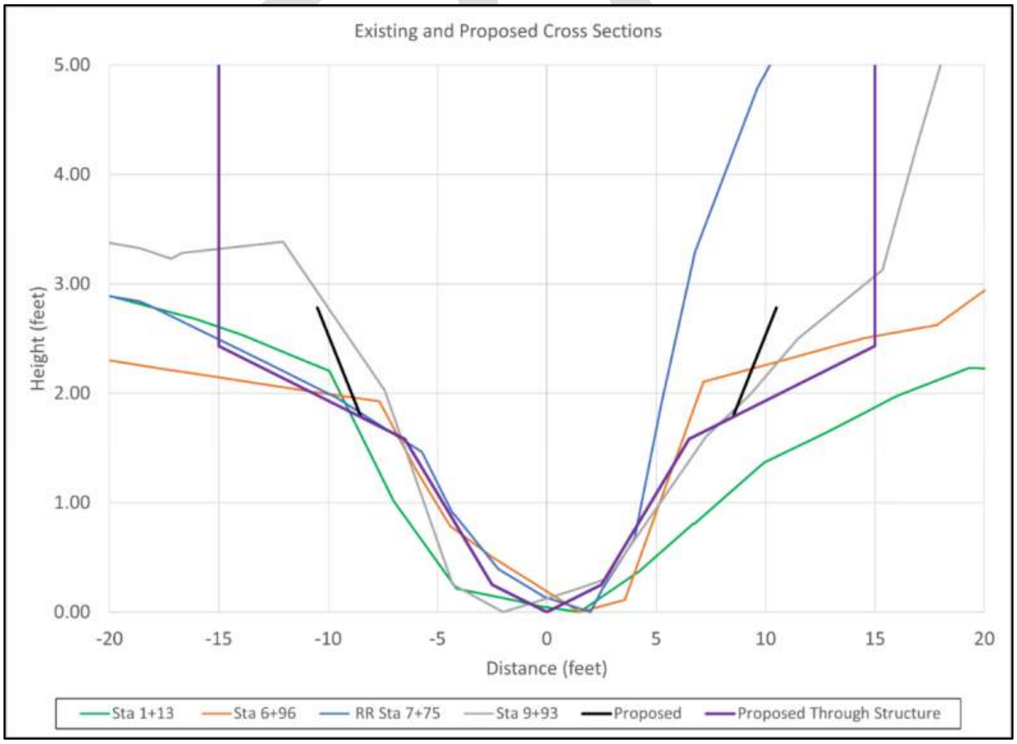

Figure 43: Proposed cross section superimposed with existing survey cross sections

The proposed cross section in Figure 43 was developed from matching the BFW measurement locations (“RR” refers to the reference reach in the figure). The proposed cross section matches the existing cross sections in the main channel and floodplain bench areas to achieve the desired minimum hydraulic opening. An additional cross section for BFW 6 is shown downstream of the SR 308 crossing (Station 1+13).

A meander belt amplitude assessment was conducted due to the unconfined nature of the channel and the natural meander of the existing channel downstream of the crossing. Section 4.2.2 includes additional information on channel sinuosity.

4.1.2 Channel Alignment

The channel exhibits no signs of lateral channel migration, and the existing crossing has not altered the natural channel alignment. For these reasons, the crossing is proposed to be replaced in its current location and to have no alterations to the existing alignment.

The proposed alignment follows the existing alignment. It extends 162 feet upstream of the existing crossing to the existing inlet opening, and then straight grades the channel through the location of the existing culvert for approximately 315 feet. Then the proposed channel follows a curved alignment for 67 feet to tie into the existing channel. The total length of grading is 558 feet. No new sinuosity is proposed with the alignment. Instead, meander bars will drive sinuosity through the crossing (see Section 4.3.2.1).

The proposed alignment is potentially problematic for a culvert crossing. The entrance angle is sharp and could pose problems for a culvert. However, the proposed culvert shown in Appendix D is the absolute maximum length. It is likely that the design structure will be shortened or will be a bridge. In this case, the entrance angle will not be problematic.

4.1.3 Channel Gradient

The upstream channel tie-in point is proposed at station 7+55, which is roughly 162 feet upstream of the existing SR 308 culvert. The downstream tie-in point is proposed at station 1+97, which is roughly 103 feet downstream of the existing SR 308 culvert. These tie-in locations avoid unusually high or low points in the existing thalweg and mimic as closely as possible the adjacent stream grades. See the proposed profile in Appendix D.

The WCDG recommends that the proposed stream channel gradient be no more than 25 percent steeper than the upstream channel gradient, meaning that the ratio of proposed channel slope to upstream channel slope is less than 1.25 (WCDG Equation 3.1). The slope of the proposed channel between proposed tie-in points is 1.7 percent. The existing upstream slope is about 1.5 percent, which results in a slope ratio of 1.13.

Long-term degradation of approximately 0.8 feet is expected to occur at this site within the lifetime of the proposed structure due to the removal of the existing culvert, as seen in Figure 71. This degradation minimal and will not need to be contained, as the proposed and equilibrium gradients match the surrounding and reference reaches. See Section 7.2 for a more detailed discussion of long-term vertical channel stability.

4.2 Minimum Hydraulic Opening

The minimum hydraulic opening is defined horizontally by the hydraulic width and the total height is determined by vertical clearance and scour elevation. This section describes the minimum hydraulic width and vertical clearance; for discussion on the scour elevation see Section 7. See Figure 44 for an illustration of the minimum hydraulic opening, hydraulic width, freeboard, and maintenance clearance terminology.

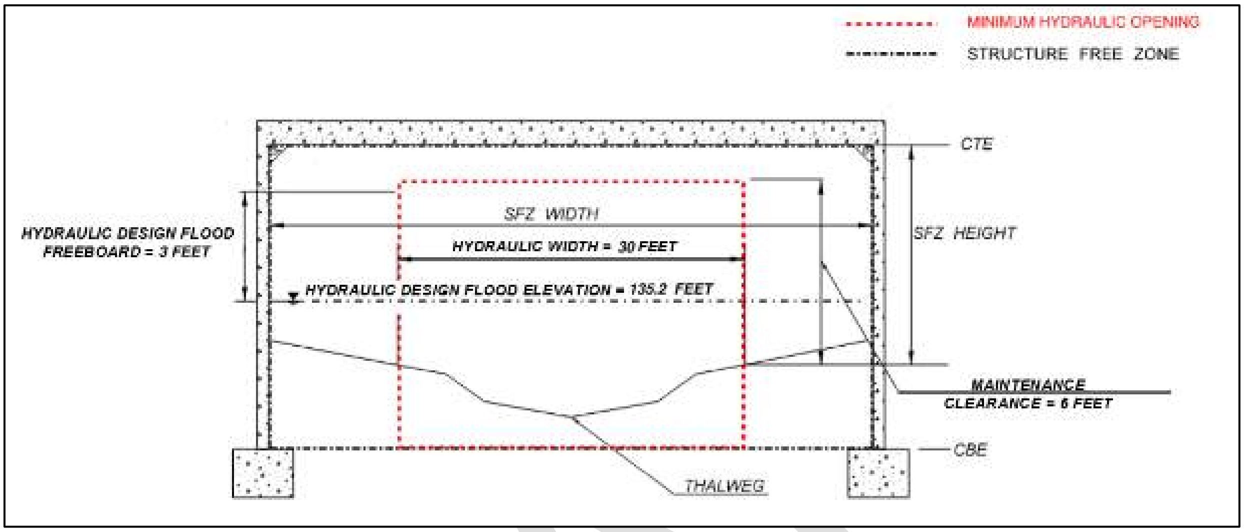

Figure 44: Minimum hydraulic opening illustration

4.2.1 Design Methodology

The proposed fish passage design was developed using the WCDG (Barnard et al. 2013) and the WSDOT *Hydraulics Manual* (WSDOT 2022a). Using the guidance in these two documents, the unconfined bridge design method was determined to be the most appropriate at this crossing because the BFW, FUR, and slope ratio fall within the applicable ranges.

The agreed-upon average BFW for Big Scandia Creek is 13.0 feet based upon measurements within the stream (see Section 2.6.1). The unconfined bridge design method is defined by the FUR (see Section 2.7.2.1), the BFWs (see Section 2.7.2), channel gradient (Section 4.1.3), channel shape (Section 4.1.1), length of crossing (see Section 4.2.4), channel stability (Sections 2.7.4 and 7.2), channel migration (see Section 2.7.5 and Section 4.1.1), and climate resilience. For the unconfined bridge design method, the WCDG recommends sizing the span of a proposed structured based the velocity ratio (defined as the average main channel velocity through the structure divided by the average main channel velocity immediately upstream of the structure if the roadway fill were removed). The velocity ratio should be close to 1 and no more than 1.1. See section 4.2.2 for discussion of the velocity ratio. The meander belt width of the channel is also considered in determining the hydraulic opening width. 7.2

4.2.2 Hydraulic Width

The starting point for the minimum hydraulic width determination of all WSDOT crossings is Equation 3.2 of the WCDG, rounded up to the nearest whole foot. For this crossing, a minimum hydraulic width of 18 feet was determined to be the minimum starting point. The WCDG also recommends in some cases to increase the minimum hydraulic opening due to excessive backwater, velocity differences between the crossing and the adjacent undisturbed reach, expected channel migration, and natural sinuosity of the channel, or if the proposed structure is considered a long crossing.

Hydraulic modeling was used to evaluate the hydraulic opening and verify the velocity ratio. A minimum hydraulic opening of 30 feet was found to have a velocity ratio of 1.0, which satisfies the velocity ratio requirements.

While the proposed crossing does not create excessive backwater or significant differences in velocities, there is a natural sinuosity of the channel through the reference reach and downstream of the crossing. A meander belt width of 20 feet to 50 feet was determined based on an evaluation of the upstream and downstream meander amplitudes. To accommodate natural channel meandering, the proposed hydraulic opening was increased from the minimum calculated hydraulic width of 18 feet to 30 feet. While there are natural channel meanders along this stream channel, there is evidence that channel migration is limited (see Section 2.7.5). Because of this limited channel migration, no additional width was added to the hydraulic width for channel migration.

Long crossings are defined as any crossings where the ratio of the crossing length to the minimum hydraulic opening exceeds 10. The length of the proposed SR 308 crossing is approximately 292 feet, which results in a length-to-width ratio of 9.7. Although this is close to being a long crossing, the proposed minimum opening of 30 feet is wider than the minimum calculated hydraulic opening (18 feet) plus 30 percent for long crossings, which would result in an opening width of approximately 23 feet (rounded up to the nearest whole foot). Future design efforts should verify roadway design requirements and forward compatibility needs at the time of design. These can impact the length of the crossing and potentially the structure free zone.

Based on the factors described above, a minimum hydraulic width of 30 feet was determined to be necessary to allow for natural processes to occur under current flow conditions. The projected 2080 100-year flow event was evaluated.

Table 7 compares the velocities of the 100-year and projected 2080 100-year events. No size increase was determined to be necessary to accommodate climate change as adequate freeboard is achieved with the proposed minimum hydraulic opening as described in section 4.2.3. Additionally, a 30-foot minimum hydraulic opening allows for a proposed channel similar in shape to the reference reach (see Section 4.1.1) and provides space for channel meandering. For detailed hydraulic results see Section 5.4.

Table 7: Velocity comparison for 30-foot structure

Location	100-year velocity (ft/s)	Projected 2080 100-year velocity (ft/s)
Downstream of structure (STA 1+84)	3.2	3.6
Downstream of structure (STA 2+67)	4.6	5.6
Through proposed 30-foot structure (STA 4+55)	5.7	6.5
Upstream of structure (STA 7+00)	3.8	4.4
Reference reach (STA 8+27)	5.7	6.4

4.2.3 *Vertical Clearance*

The vertical clearance under a structure is made up of two considerations: freeboard and maintenance clearance. Both are discussed below, and results are summarized in Table 8.

The minimum required freeboard at the project location, based on bankfull width and structure width, is 2 feet above the 100-year water surface elevation (WSE) (Barnard et al. 2013; WSDOT 2022a). The WSDOT Hydraulics Manual requires 3 feet of freeboard for all structures greater than 20 feet and on all bridge structures unless otherwise approved by HQ Hydraulics (WSDOT 2022a). The proposed minimum hydraulic width is 30 feet; therefore 3 feet of freeboard is required.

WSDOT is incorporating climate resilience in freeboard, where practicable, and has evaluated freeboard at both the 100-year WSE and the projected 2080 100-year WSE. The WSE is projected to increase by 0.7 feet for the 2080 projected 100-year flow rate. The minimum required freeboard at this site will be applied above the projected 2080 100-year WSE to accommodate climate resilience.

The second vertical clearance consideration is maintenance clearance. WSDOT HQ Hydraulics determines a required maintenance clearance if a height is required to maintain habitat elements, such as boulders or large woody material (LWM). If there are no habitat elements requiring maintenance clearance to maintain, the maintenance clearance is only a recommendation by WSDOT HQ Hydraulics, and the region determines the maintenance clearance required.

The channel complexity features in Section 4.3.2 do not include elements of significant size and will not need to be maintained with machinery. If it is practicable to do so, a minimum maintenance clearance of 6 feet is recommended for maintenance and monitoring purposes but is not a hydraulic requirement. Maintenance clearance is measured from the highest streambed ground elevation within the horizontal limits of the minimum hydraulic width.

Table 8: Vertical clearance summary

Parameter	Downstream face of structure	Upstream face of structure
Station	3+06	5+99
Thalweg elevation (ft)	129.5	134.6
Highest streambed ground elevation within hydraulic width (ft)	131.9	137.0
100-year WSE (ft)	133.3	137.7
2080 100-year WSE (ft)	134.0	138.4
Required freeboard (ft)	3.0	3.0
Recommended maintenance clearance (ft)	6.0	6.0
Required minimum low chord, 100-year WSE + freeboard (ft)	136.3	140.7
Required minimum low chord, 2080 100-year WSE + freeboard (ft)	137.0	141.4
Recommended minimum low chord, highest streambed ground elevation within hydraulic width + maintenance clearance (ft)	137.9	143.0
Required minimum low chord (ft)	137.0	141.4
Recommended minimum low chord (ft)	137.9	143.0

4.2.3.1 Past Maintenance Records

WSDOT Area 2 Maintenance was contacted to determine whether there are ongoing maintenance problems at the existing structure because of LWM racking at the inlet or sedimentation. The maintenance representatives indicated that there was no record of LWM blockage and/or removal or sediment removal at this crossing.

4.2.3.2 Wood and Sediment Supply

The drainage basin for Big Scandia Creek upstream of the crossing is approximately 54 percent forested, and there are no known plans for development or land cover changes in the basin. During site investigations, no LWM was observed racking upstream of the crossing, as noted in Section 4.2.3.1, LWM was observed further upstream but was limited to a 12-inch diameter or less. There are no records of maintenance issues at this location. The stream itself is relatively small and has limited ability to move LWM even during the 100-year event (247.6 cfs). The creek appears to be in equilibrium from a sediment supply perspective, and there are only limited signs of aggradation or degradation in existing conditions due to the undersized culvert (see Section 2.3 and Section 2.7.3). As noted in Section 4.1.3, aggradation is not anticipated to occur in the proposed conditions.

4.2.4 Hydraulic Length

A minimum hydraulic width of 30 feet is recommended up to a maximum hydraulic length of 292 feet. If the hydraulic length is increased beyond the 292 feet, the hydraulic width and vertical clearance will need to be reevaluated. It is recommended that a shorter hydraulic length be evaluated to allow increased meander downstream of the crossing.

4.2.5 Future Corridor Plans

There are currently no long-term plans to improve SR 308 through this corridor.

4.2.6 Structure Type

No structure type has been recommended by WSDOT HQ Hydraulics. The layout and structure type will be determined at later project phases.

4.3 Streambed Design

This section describes the streambed design developed for Big Scandia Creek at SR 308 MP 1.15.

4.3.1 Bed Material

The development of the proposed streambed mix followed methods recommended in the WCDG (Barnard et al. 2013) for sizing streambed material in culverts and the WSDOT Hydraulics Manual (WSDOT 2022a). The proposed streambed mix design is intended to mimic the average of the three pebble counts (see Section 2.7.3). The streambed material gradation was proportioned to mimic natural conditions to the extent practical using WSDOT standard streambed mixes (WSDOT 2022b). These bed material mixes are well-graded material with larger, less mobile particle sizes while also including smaller, mobile particle sizes to produce a porosity that minimizes the opportunity for flow in the stream to go entirely subsurface during low-flow periods. The finer portion of the gradation will be composed of silts, sands, and small gravels to fill the interstitial spaces of the larger portions of the gradation.

The proposed streambed material should be constructed utilizing 75 percent Streambed Sediment, WSDOT Standard Specification 9-03.11(1); and 25 percent 4-inch cobbles, WSDOT Standard Specification 9-03.11(2). This standard material matches relatively well with the existing stream gradation (see Table 9). WSDOT Streambed Sediment has the smallest gradation sizes of the standard mixes without the need for a special provision. The minimum allowable streambed depth will be determined based on scour calculations during later design stages. See Appendix C for the supporting calculations for this analysis.

Table 9: Comparison of observed and proposed streambed material

Sediment size	Observed diameter for design (in)	Proposed streambed material diameter (in)	Proposed meander bar tail material diameter (in)	Proposed meander bar head material diameter (in)
$\mathbf{D_{16}}$	0.4	0.1	0.8	1.1
$\mathbf{D_{50}}$	0.9	1.2	4.4	13.7
$\mathbf{D_{84}}$	1.8	2.3	13.2	16.6
$\mathbf{D_{95}}$	2.4	3.0	16.5	17.6
$\mathbf{D_{100}}$	4.7	4.0	18.0	18.0

The Bathurst method, as recommended by WDFW, is not recommended for use in streams with gradients less than 4 percent (Barnard et al. 2013). The design slope for the proposed Big Scandia Creek to Liberty Bay is 1.7 percent (see Section 4.1.3). Therefore, the assessment of the streambed material did not use the Bathurst method. Instead, the assessment of streambed material used the modified Shields critical shear stress approach, as described in the U.S. Forest Service Stream Simulation guidelines (USDA 2008), to verify whether the proposed sediment sizes are mobile or stable during the full range of design flows. This method compares the critical shear stress for incipient motion for the D_{84} size fraction of the proposed streambed mixture to the average applied shear stress within the proposed grading limits for the 100-year peak flow. The incipient motions for flows other than 100-year peak flows were also checked.

These channel stability calculations indicate that D_{50} and D_{84} sediments will be mobile during all modeled flows. This is acceptable due to sufficient sediment transport from upstream, as discussed in Section 2.7.4. There are no barriers upstream of the channel.

Meander bars are recommended at a minimum spacing of 50 feet through the restored channel area to increase channel bed stability and to match the natural sinuosity of the reference reach. The meander bars will also mimic forcing elements typically found in pool-riffle systems to prevent a shift to a plane-bed morphology through the crossing. The design will incorporate meander bars so that a low-flow channel can be introduced with enough complexity to facilitate fish passage through the structure. The meander bar heads should consist of 30 percent Streambed Sediment (9-03.11(1)) and 70 percent 12- to 18-inch streambed boulders (9-03.11(2)). The meander bar head's D_{50} and D_{84} is stable during the 100-year flow, which satisfies WSDOT meander bar guidance. The meander bar tail should consist of 30 percent Streambed Sediment (9-03.11(1)), 50 percent 12-inch cobble materials (9-03.11(2)), and 20 percent 12- to 18-inch streambed boulders (9-03.11(2)). WSDOT meander bar guidance dictates that the meander bar tail should consist of 50% or higher by volume larger than the D84 of the stream to dissipate overtopping energy. The proposed meander bar tail D_{50}, as seen in Table 9, is larger than the proposed streambed D_{84}. No stability requirements are specified for the meander bar tail, but the D_{84} of this gradation is stable during the 10-year flow. Because of this stability and the steady sediment supply in this stream (see Section 2.3), the meander bar tail will be stable during regular storm events. See Appendix C for detailed results of the meander bar mobility analysis. The boulders used in the meander bars are comparable to boulders already observed in the system, as discussed in Section 2.7.3.

4.3.2 Channel Complexity

This section describes the channel complexity of the streambed design developed for Big Scandia Creek at SR 308 MP 1.15.

4.3.2.1 Design Concept

The channel is designed as a pool-riffle channel. Channel complexity features for the SR 308 crossing are designed to provide habitat and allow for natural stream processes. The channel complexity features for this crossing include LWM in restored open-channel areas and meander bars within the crossing for habitat. LWM are wood structures (trunks) larger than 6 feet in length and greater than 6 inches in diameter. When LWM is used appropriately within a channel, it can provide bank protection and channel resilience, and can offer benefits for aquatic habitat. Habitat provided by LWM can help aquatic life shelter from predators and can contribute to hyporheic flows, cooler waters, and gravel/sediment retention and generally improves ecological integrity. Preformed pools are not recommended through the crossing. Meander bars will mimic forcing elements typically found in pool-riffle systems to naturally create pools and prevent a shift to a plane-bed morphology through the crossing. The design will incorporate meander bars so that a low-flow channel can be introduced that has enough complexity to facilitate fish passage through the structure. The bed and bank morphology of the existing channel is stable; vegetation on the bank contributes to the stability of the channel, LWM will be used to add channel complexity and refuge for fish.

The project will reconstruct 558 feet of channel, roughly 292 feet of which is expected to be within the new structure if a culvert is constructed, leaving 266 feet of open-channel area. A bridge design would increase the open channel length along the constructed reach. For this length of reconstructed channel, the 75th percentile wood targets, in accordance with Fox and Bolton and the WSDOT Hydraulic Manual, are 19 key pieces, 65 total pieces of LWM, and a volume of 220.3 cubic yards (Fox and Bolton 2007; WSDOT 2022a). To achieve the recommended volume of wood, the LWM would need to be up to 4 feet diameter at breast height (DBH). Pieces this size would be difficult to obtain, difficult to construct, and excessive for this 13.0-foot-wide channel. For these reasons, the recommended wood volumes are reduced at this site.

Key pieces will consist of logs that are generally 1.5 feet to 2.0 feet DBH and 24 feet to 30 feet long. Additional pieces in the 1-foot DBH size range will be included along with smaller, more mobile wood in the 0.5-foot DBH range. The logs have been classified into five distinct log types both with and without rootwads and are identified as type A through E on the figures. Mobile pieces would move only during extreme events and may not move far even during high flows, because they are likely to rack against larger wood pieces. The project is anticipated to use anchoring for LWM until stability calculations are completed that indicate otherwise. Appendix F shows the recommended quantities of LWM for this channel.

Figure 45 shows a conceptual layout of wood recommended for this channel assuming a culvert structure is selected. Note that the length of modified channel outside of the crossing will be limited relative to the overall length of the crossing. As a result, placement of LWM in proximity to the crossing (less than 50 feet) will be required. The 75th percentile wood volume and total piece targets are not feasible for this crossing for a culvert concept as the number and size of the LWM would be overly dense and counterproductive to fish passage. As shown in Figure 45, the proposed design contains the recommended number of key pieces, but only 41 total pieces instead of the recommended 65. Figure 46 shows a conceptual layout of wood recommended for this channel assuming a bridge structure is selected. Note that the increased length of open channel as compared to the culvert concept allows for the targeted total number of pieces and number of key pieces to be exceeded.

Meander bars, as well as LWMs, are designed to be immobile during low-flow and medium-flow events, as discussed in Section 4.3.1, to help maintain the low-flow channel even after a larger flow event. The meander bars mimic the natural sinuosity of the channel around the crossing. Upstream of the crossing the meanders have an average length-to-width ratio of 4.4. Downstream of the crossing, the length-to-width ratio drops to 1.9. In order to illustrate this transition from longer, narrower meanders upstream to shorter, wider meanders downstream, the proposed meander bars have a length-to-width ratio of 3.3, which is nearly the average between the upstream and downstream reaches. A low-flow channel will be formed through the LWM and will connect with the low-flow channel formed between meander bars under the structure. The low-flow channel will ensure that during low flows, there is no risk of fish stranding in the dry bed. The LWM anchors not only can provide stability but also could provide small pools, which would improve habitat and provide refuge to juveniles when they are migrating upstream.

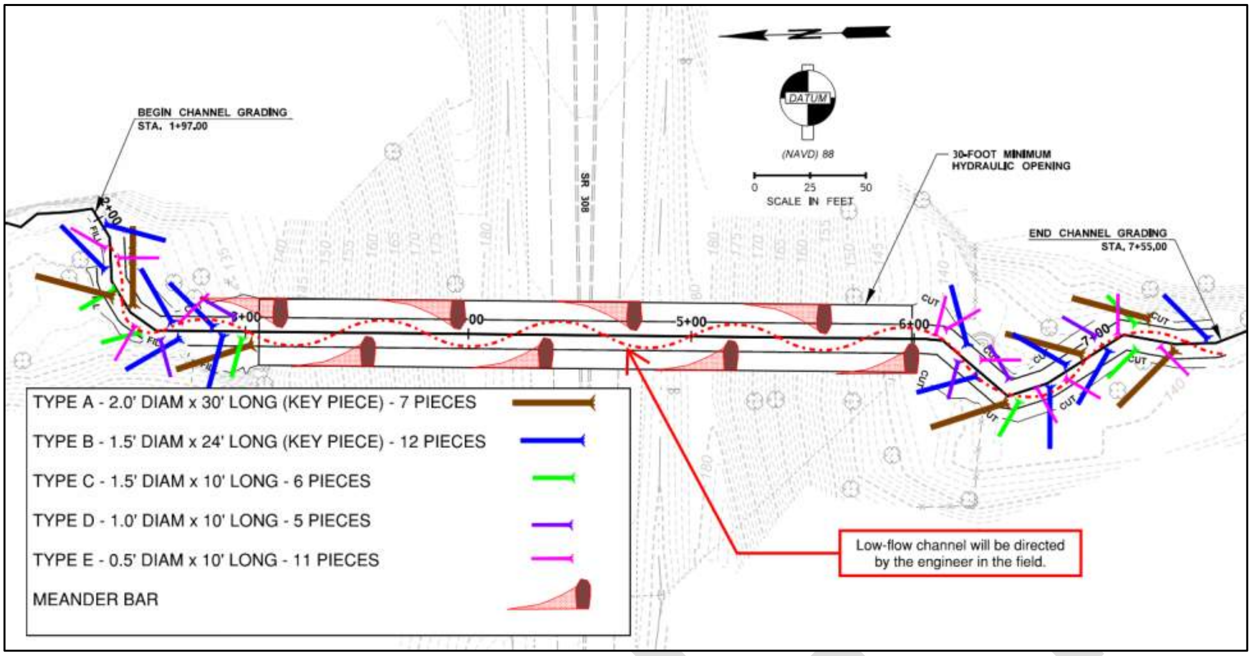

Figure 45: Conceptual layout of habitat complexity – culvert

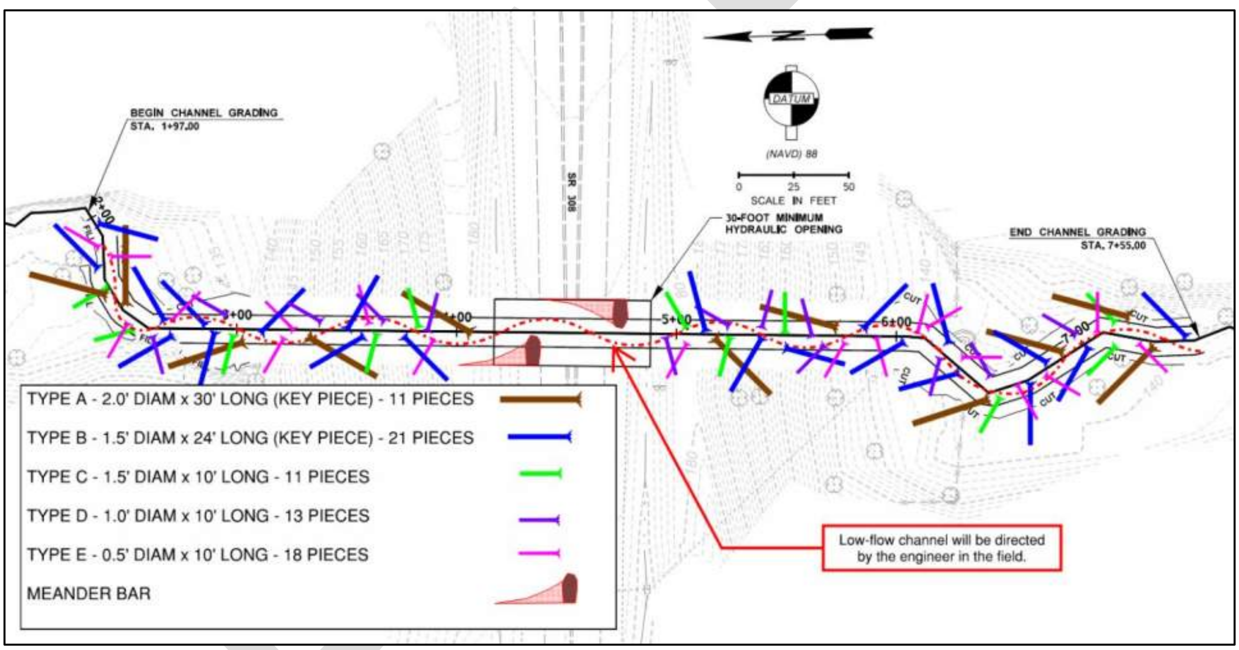

Figure 46: Conceptual layout of habitat complexity – bridge

4.3.2.2 Stability Analysis

Large wood stability analysis will be completed at final design.

5 Hydraulic Analysis

The hydraulic analysis of the existing and proposed SR 308 MP1.15 Big Scandia Creek crossing was performed using the United States Bureau of Reclamation's (USBR's) SRH-2D Version 3.2 computer program, a two-dimensional (2D) hydraulic and sediment transport numerical model (USBR 2017). Pre- and post-processing for this model was completed using SMS Version 13.1.14 (Aquaveo 2021).

Three scenarios were analyzed for determining stream characteristics for Big Scandia Creek with the SRH-2D models: (1) existing conditions with the 6.0-foot-diameter, 292-foot-long corrugated metal culvert, (2) natural conditions without the presence of a culvert, and (3) proposed conditions with the proposed 30-foot minimum hydraulic opening installed. Results are discussed in Section 5.2 discusses results from the existing conditions model, and Section 5.3 discusses results from the natural conditions model. Section 5.4 discusses results from the proposed conditions model. See Appendix H for graphical representations of the 2D model results for the three scenarios.

5.1 Model Development

This section describes the development of the model used for the hydraulic analysis and design.

5.1.1 Topographic and Bathymetric Data

The channel geometry data in the model were obtained from the MicroStation and InRoads files supplied by the WSDOT Project Engineer's Office (PEO), which were developed from topographic surveys performed by WSDOT on December 6, 2021. The survey data extends approximately 335 feet upstream and 320 feet downstream of the SR 308 crossing. The survey data was supplemented with light detection and ranging (LiDAR) data (Washington LiDAR Portal 2017). Proposed channel geometry was developed from the proposed grading surface created by DEA. All survey and LiDAR information is referenced against the NAVD88 vertical datum, and NAD 1983 State Plan Washington North horizontal datum. The survey and LiDAR data revealed rather consistent channel shape and confined floodplain banks.

Topographic surface development of the site geometry for the proposed conditions used InRoads to regrade the surface through the existing crossing and extending approximately 155 feet upstream and 103 feet downstream of the existing SR 308 crossing. Modeling of both the natural and proposed conditions used an identical cross section mimicking the channel geometry in the reference reach. Upstream and downstream match points to the existing profile were selected to find an average, consistent grade that would minimize the increase in the longitudinal gradient of the channel.

5.1.2 Model Extent and Computational Mesh

The model extends from approximately 900 feet upstream of the existing culvert inlet to approximately 300 feet downstream of the existing culvert outlet, covering a total channel length of 1,500 feet. The model limits were selected to ensure that, at steady conditions, the boundary conditions would not influence the flow at the structure.

The total mesh area encompasses 4.4 acres. The model meshes have an element density that reflects the complexity of the site conditions. The existing conditions model consists of 19,000 elements; the natural conditions model consists of 20,677 elements; and the proposed conditions model consists of 19,402 elements (see Figure 47, Figure 48, and Figure 49, respectively). All meshes utilize quadrilateral elements in the channel and on the roadway and triangular elements over the remaining surface area. The meshes have an approximate vertex spacing of 2.5 feet to 4 feet along the channel banks and an approximate 10-foot vertex spacing near the outer mesh limits. The vertex spacing varies slightly through the main body of the channel, having a higher density at the crossing for an increased level of detail at this location.

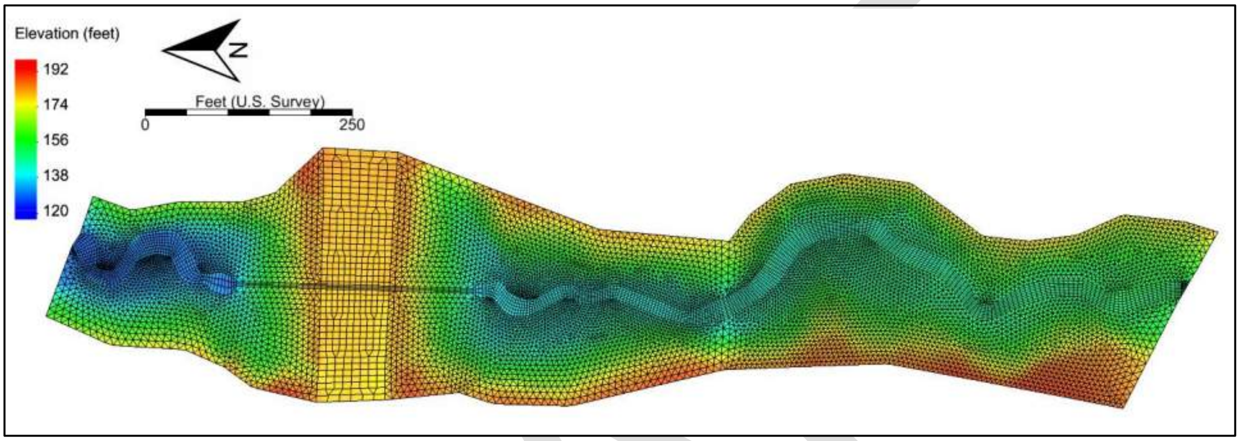

Figure 47: Existing-conditions computational mesh with underlying terrain

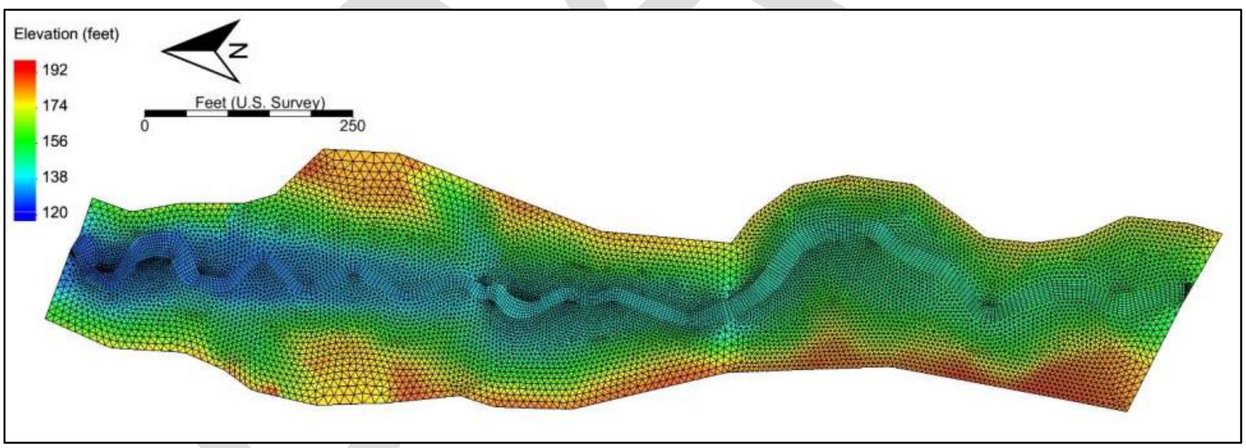

Figure 48: Natural-conditions computational mesh with underlying terrain

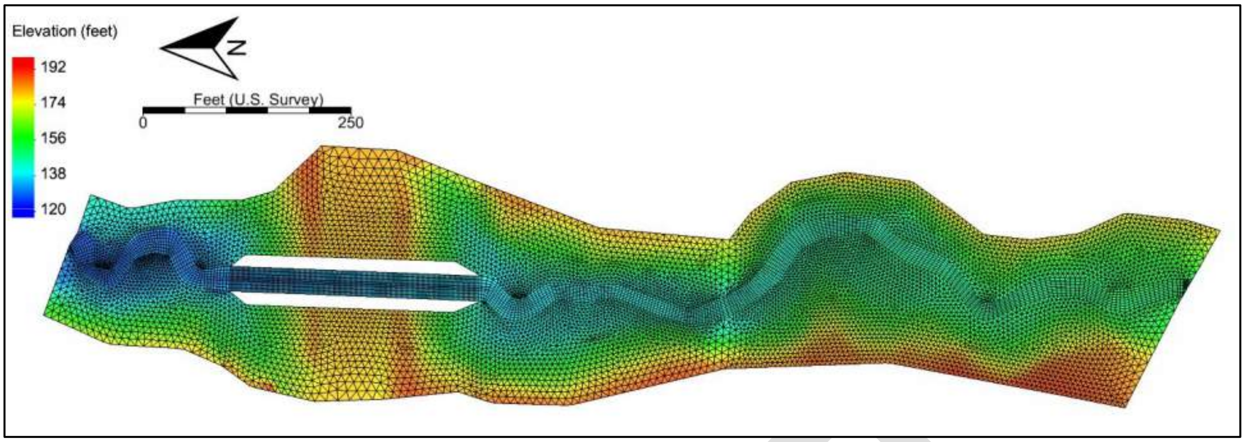

Figure 49: Proposed-conditions computational mesh with underlying terrain

5.1.3 Materials/Roughness

Table 10 lists the roughness coefficients used in the hydraulic modeling, which are taken from WSDOT Hydraulics Manual (WSDOT 2022a) Appendix A4 and evaluated by visual observation in the field. Existing, natural, and proposed conditions used the same roughness values. No-flow areas (i.e., buildings) and unassigned land cover types were not necessary to model the three conditions. Figure 50, Figure 51, and Figure 52 show the spatial distribution of the roughness conditions for the existing conditions, the natural conditions and the proposed conditions modeling, respectively.

The main channel roughness value represents a gravel and cobble bottom without vegetation in the stream. The channel banks are representative of light brush and vegetation, while the vegetated slopes are similar to the channel banks but have a higher roughness value to account for trees. The existing conditions, natural conditions, and proposed conditions roughness coverages are the same except within the vicinity of the proposed channel. The proposed channel will include LWM, and channel-spanning logs, as discussed in Section 4.3.2, which will drastically increase the roughness compared to existing conditions. Within the proposed structure, the channel will not contain any LWM, but meander bars will be included to increase roughness and reduce velocities through the proposed structure. The meander bars and coarser streambed material lead the design team to increase the constructed channel roughness relative to the existing channel.

Table 10: Manning's n hydraulic roughness coefficient values used in the SRH-2D model

Material	Manning's n
Asphalt	0.016
Channel (gravels, cobbles, minimum. vegetation.)	0.04
Overbank (heavy vegetation)	0.07
Overbank (light vegetation)	0.06
Channel (constructed)	0.06
Channel (LWM)	0.11

Figure 50: Spatial distribution of existing-conditions roughness values in SRH-2D model

Figure 51: Spatial distribution of natural-conditions roughness values in SRH-2D model

Figure 52: Spatial distribution of proposed-conditions roughness values in SRH-2D model

5.1.4 Boundary Conditions

The existing conditions model contains four boundary conditions: a constant inflow rate at the upstream limit, paired inlet and outlet boundaries at the existing culvert location, and a WSE at the downstream limit. The existing conditions model used a pair of boundary condition arcs to simulate the existing 72-inch-diameter culvert crossing SR 308 at the project site. The SRH-2D model simulates the culvert hydraulics by running the Federal Highway Administration's HY-8 culvert analysis software as an imbedded program within SMS and uses the boundary conditions as the interface between the programs. Culvert geometry, type, and other relevant site data required for the HY-8 computations were compiled from the WSDOT survey and DEA site visit. Figure 53 shows the HY-8 input data for the SR 308 culvert in the existing conditions model.

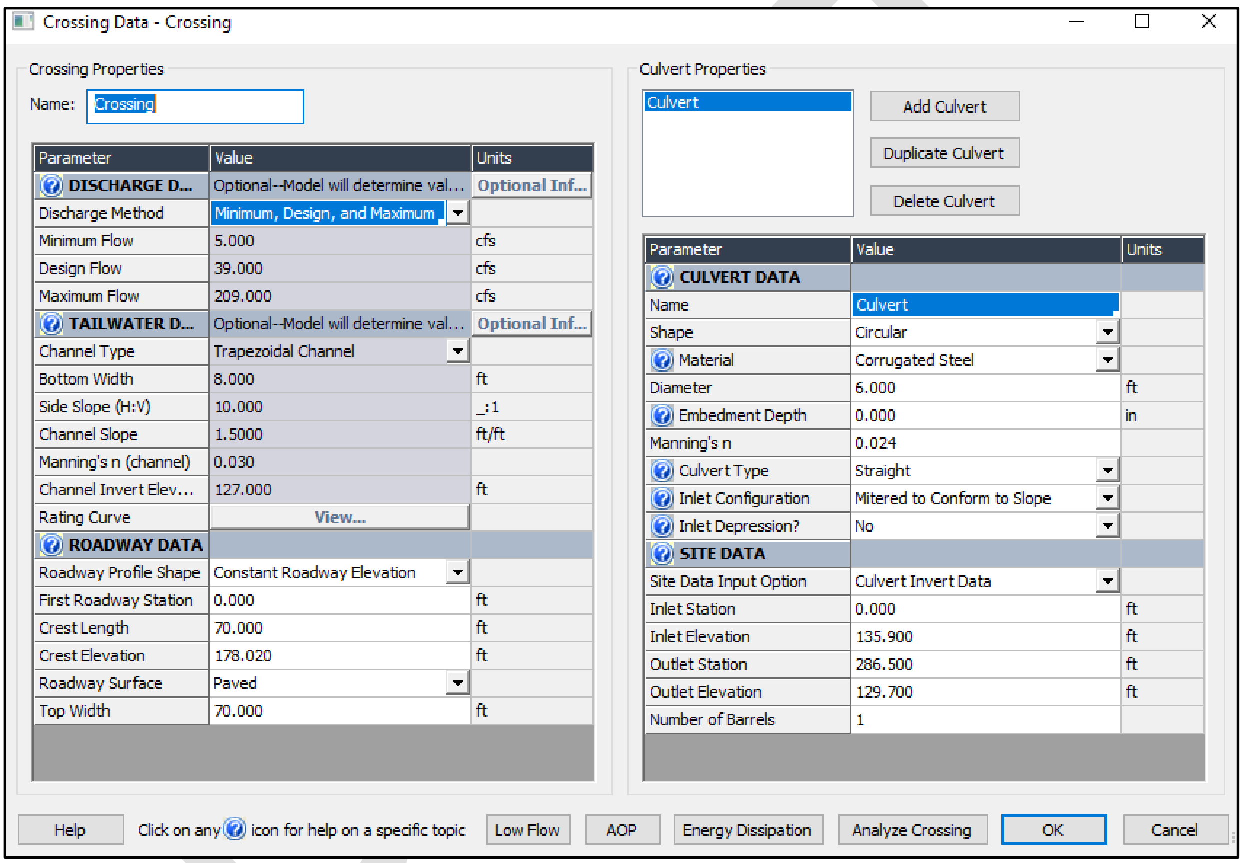

Figure 53: HY-8 culvert parameters

The natural conditions and proposed conditions models include two boundary conditions: an inflow rate at the upstream limits and a WSE at the downstream limits of the model. Figure 54 shows the locations of these boundaries in the existing conditions model, and Figure 55 shows the locations of these boundaries in the natural conditions and proposed conditions models.

For all conditions, the upstream inflow boundary was specified as a constant flow rate corresponding to the peak flow for the recurrence interval being modeled (i.e., peak flows equal to the 2-year, 100-year, 500-year, and predicted 2080 100-year events). Table 6 in Section 3 provides these flows rates. The downstream outflow boundary was set to a constant WSE equal to the normal water depth elevation calculated from a composite Manning's n of 0.035, a slope of 0.015 foot/foot, the flow values corresponding to each event, and a channel cross section based on survey data at the boundary condition location. Figure 56 shows a rating curve for the inflow boundary condition and WSE for each modeled event. The calculated downstream WSEs at the outflow boundary condition were 126.8 feet, 128.5 feet, 128.7 feet, and 129.0 feet for the 2-year, 100-year, 500-year, and 2080 100-year events, respectively. The inflow and outflow boundary conditions were set sufficiently far from the crossing that these boundaries do not influence the hydraulic results at the project site. The model was run in steady-state mode for all simulated flows.

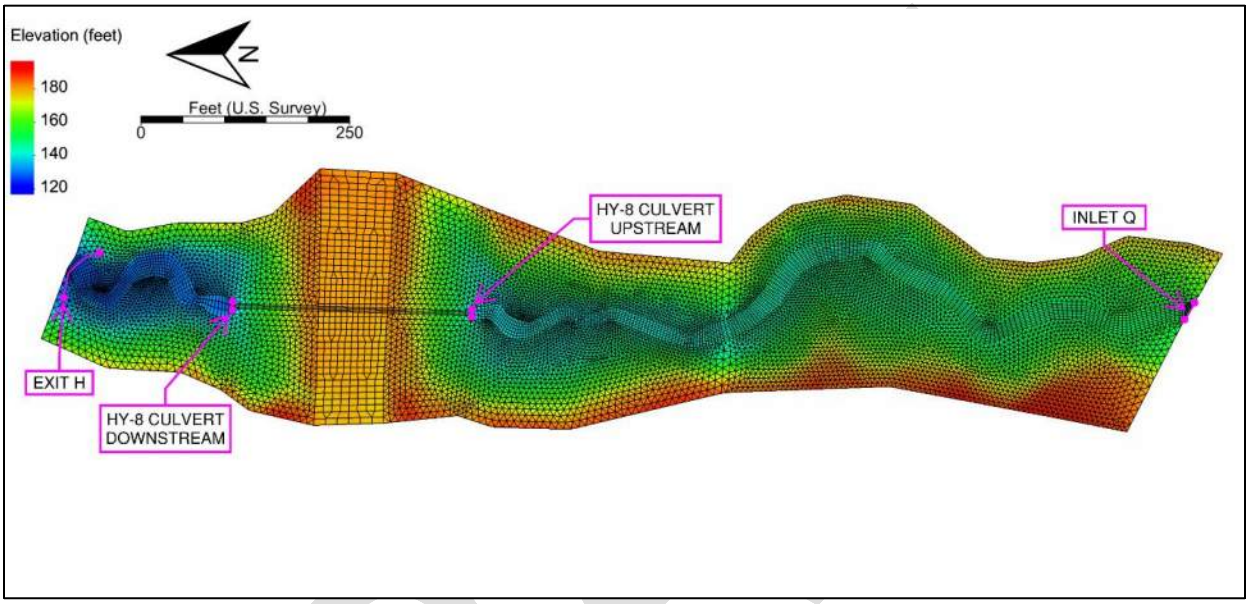

Figure 54: Existing-conditions boundary conditions

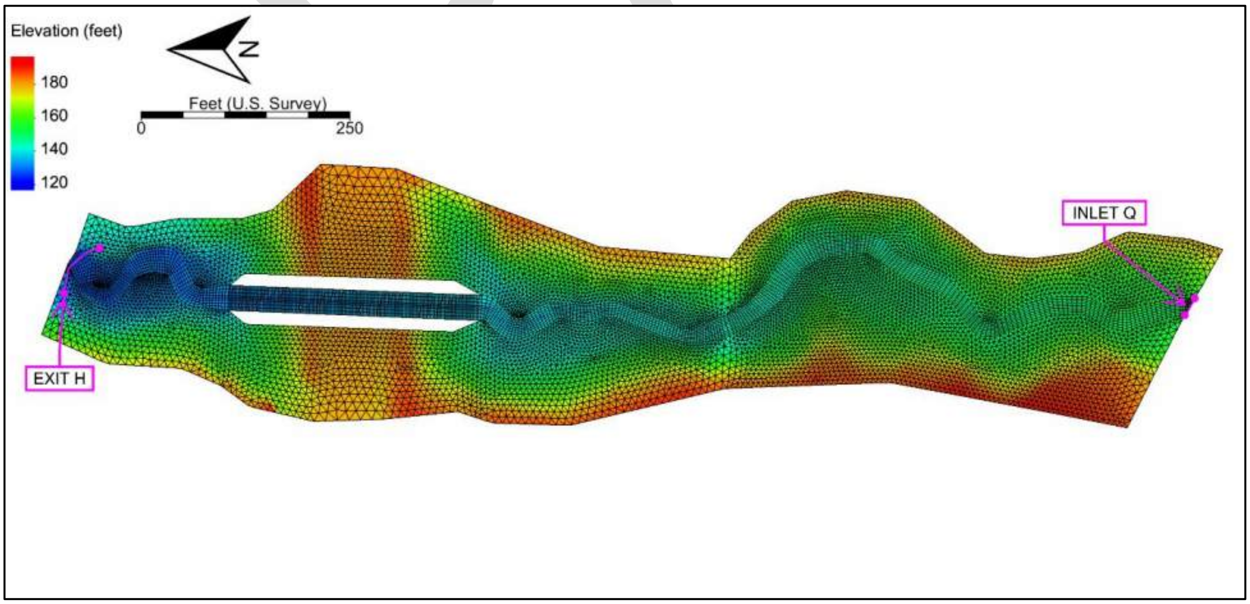

Figure 55: Natural-conditions and proposed-conditions boundary conditions

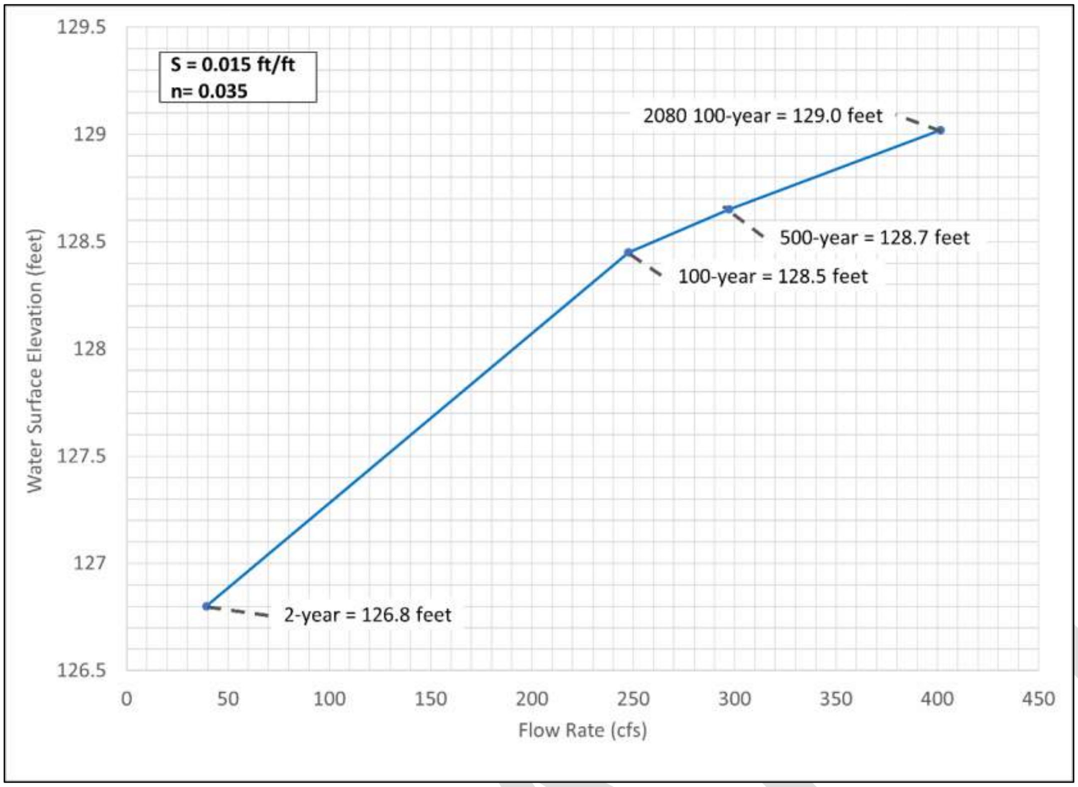

Figure 56: Downstream outflow boundary condition normal depth rating curve

5.1.5 Model Run Controls

The existing and proposed models were run as steady-state flow until there was no observable change in WSE upstream or downstream of the crossing. The existing, natural, and proposed conditions model runs started at time 0 hours and ended at time 3.0 hours using 1.0-second time steps. The model runs typically achieved steady-state conditions in less than 1 hour of simulation time. Appendix I contains monitor point and monitor line plots showing model stability and continuity over the model run time. The existing, natural, and proposed simulations began with a dry initial condition and event-specific flow values. All simulations used the default parabolic turbulence value of 0.7. A hydraulic model review was completed.

5.1.6 Model Assumptions and Limitations

The model assumes that all of the flow in the basin enters the channel at the upstream boundary condition in a uniform condition, even though the runoff between SR 308 and the upstream boundary condition would enter the channel throughout this reach. The model was run in a steady-state condition and was calibrated to ensure stability. No high-water marks or other indicators were available for validation.

5.2 Existing Conditions

The existing SR 308 crossing conveys all flow between the 2-year and 500-year intervals without overtopping SR 308. Flow splits or multiple openings were not present in the existing conditions model. The maximum modeled flow through the existing structure is 297.1 cfs. WSE profile plots show backwater during all modeled events greater than the 2-year under existing conditions. Model results for the existing conditions hydraulic model were extracted using observation arcs in SRH-2D. Three cross sections were placed at locations that represent typical downstream conditions, and another three were placed at locations that represent typical upstream conditions. Two cross sections were placed within the placed within the proposed grading limits, one upstream and one downstream of the crossing. Figure 57 shows the locations of the cross sections where the model data was extracted. Cross section F is located within the reference reach. The results extracted from the hydraulic model were processed using an Excel spreadsheet to determine average or maximum values within the main channel (determined from 2-year flood extents) as well as left overbank (LOB) and right overbank (ROB) areas for each cross section. See Table 11 and Appendix H for the processed results from the SRH-2D hydraulic model. Figure 58 and Figure 59 show the existing conditions profile and the existing conditions typical cross section (at station 7+00 upstream of the crossing), respectively, for the hydraulic results analyzed.

Maximum flow depths within the modeled area ranged from 1.1 foot to 2.1 feet during the 2-year event, with a majority of the modeled reach having maximum flows depths of 1.5 foot to 1.9 feet. Velocities during the 2-year event along the stream centerline ranged from 1.2 to 3.2 feet per second (fps) in the modeled reach, with a majority of the modeled reach having velocities of 1.7 fps to 2.4 fps. Lower velocities are associated with areas that are backwatered immediately upstream of the culvert during the 100-year and 500-year.

Maximum flow depths within the model varied during the 100-year event due to the backwater condition at the culvert inlet. A maximum depth of 6.1 feet was modeled at the culvert inlet during the 100-year event, compared to the typical maximum depth of 2.7 feet to 3.8 feet downstream of the culvert. The maximum velocity at the culvert outlet during the 100-year event was 6.6 fps at the exit of the plunge pool (see Figure 19). A maximum water depth of 7.8 feet was modeled during the 500-year event immediately upstream of the culvert, which produced velocities at the culvert outlet of approximately 6.9 fps. 100-year main channel velocities ranged from 1.5 fps to 6.6 fps at the selected cross sections, while LOB and ROB velocities in the floodplain ranged from 0.4 fps to 5.0 fps, as shown in Figure 60 and Table 12.

Shear stresses were consistently highest at the culvert outlet because of the greater velocities at this locations. Reported shear stress immediately upstream of the culvert in the backwatered area during the 500-year event is low due to the small velocities at those locations when the model reaches steady state. Typical shear stress values in the reference reach during the 2-year through 500-year events are low ranging from 0.2 to 0.8 pounds per square foot.

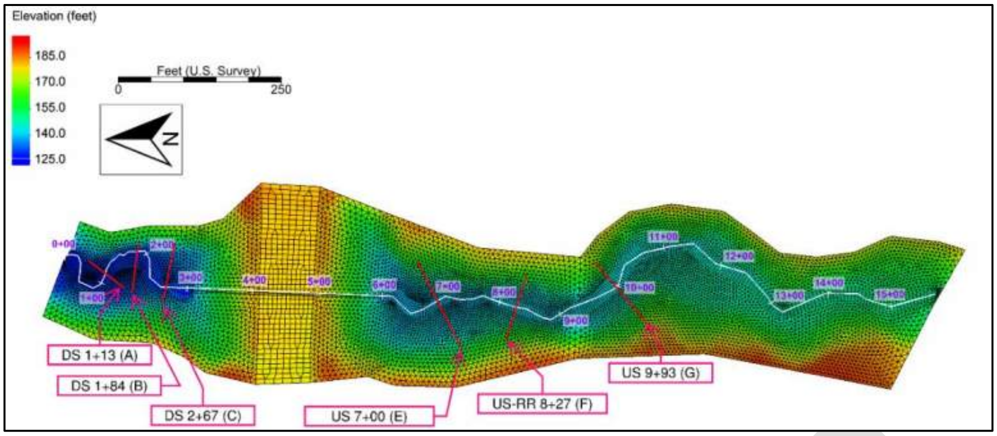

Figure 57: Locations of cross sections used for results reporting

Table 11: Average main channel hydraulic results for existing conditions

Hydraulic parameter	Cross section	2-year	100-year	500-year
Average WSE (ft)	DS 1+13 (A)	128.8	130.3	130.6
	DS 1+84 (B)	130.2	131.7	131.9
	DS 2+67 (C)	130.4	131.9	132.1
	Structure (D)	NA	NA	NA
	US 7+00 (E)	139.4	143.6	145.3
	US-RR 8+27 (F)	140.8	143.7	145.3
	US 9+93 (G)	142.3	144.1	145.4
Max depth (ft)	DS 1+13 (A)	1.1	2.7	2.9
	DS 1+84 (B)	1.9	3.8	4.1
	DS 2+67 (C)	1.5	3.1	3.3
	Structure (D)	NA	NA	NA
	US 7+00 (E)	1.9	6.1	7.8
	US-RR 8+27 (F)	2.1	4.9	6.6
	US 9+93 (G)	1.5	3.4	4.6
Average velocity (ft/s)	DS 1+13 (A)	2.4	5.6	5.8
	DS 1+84 (B)	1.2	2.7	3.1
	DS 2+67 (C)	3.2	6.6	6.9
	Structure (D)	NA	NA	NA
	US 7+00 (E)	1.5	1.5	1.2
	US-RR 8+27 (F)	1.7	2.5	1.8
	US 9+93 (G)	2.2	5.4	3.7
Average shear (lb/SF)	DS 1+13 (A)	0.5	2.0	2.1
	DS 1+84 (B)	0.2	0.8	0.8
	DS 2+67 (C)	1.3	3.5	3.8
	Structure (D)	NA	NA	NA
	US 7+00 (E)	0.2	0.1	0.1
	US-RR 8+27 (F)	0.2	0.3	0.1
	US 9+93 (G)	0.4	1.1	0.4

Main channel extents were approximated using the 2-year event water surface top widths.

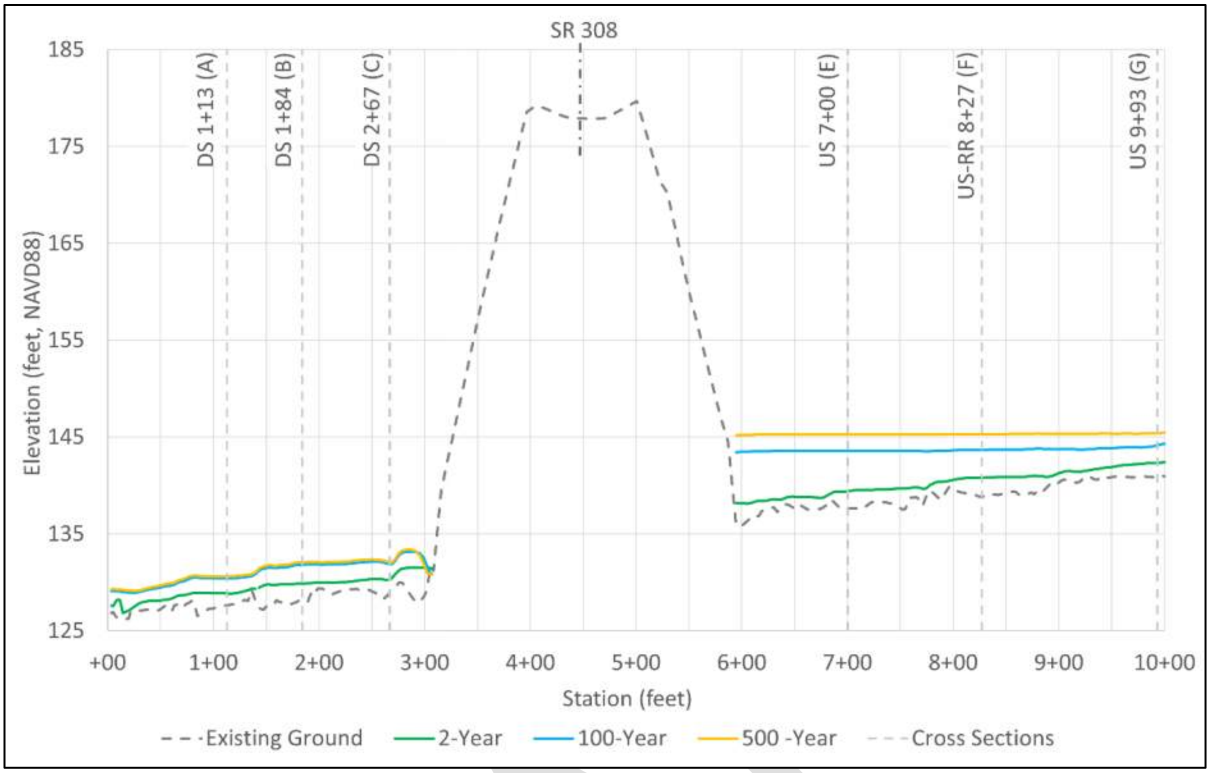

Figure 58: Existing-conditions water surface profiles

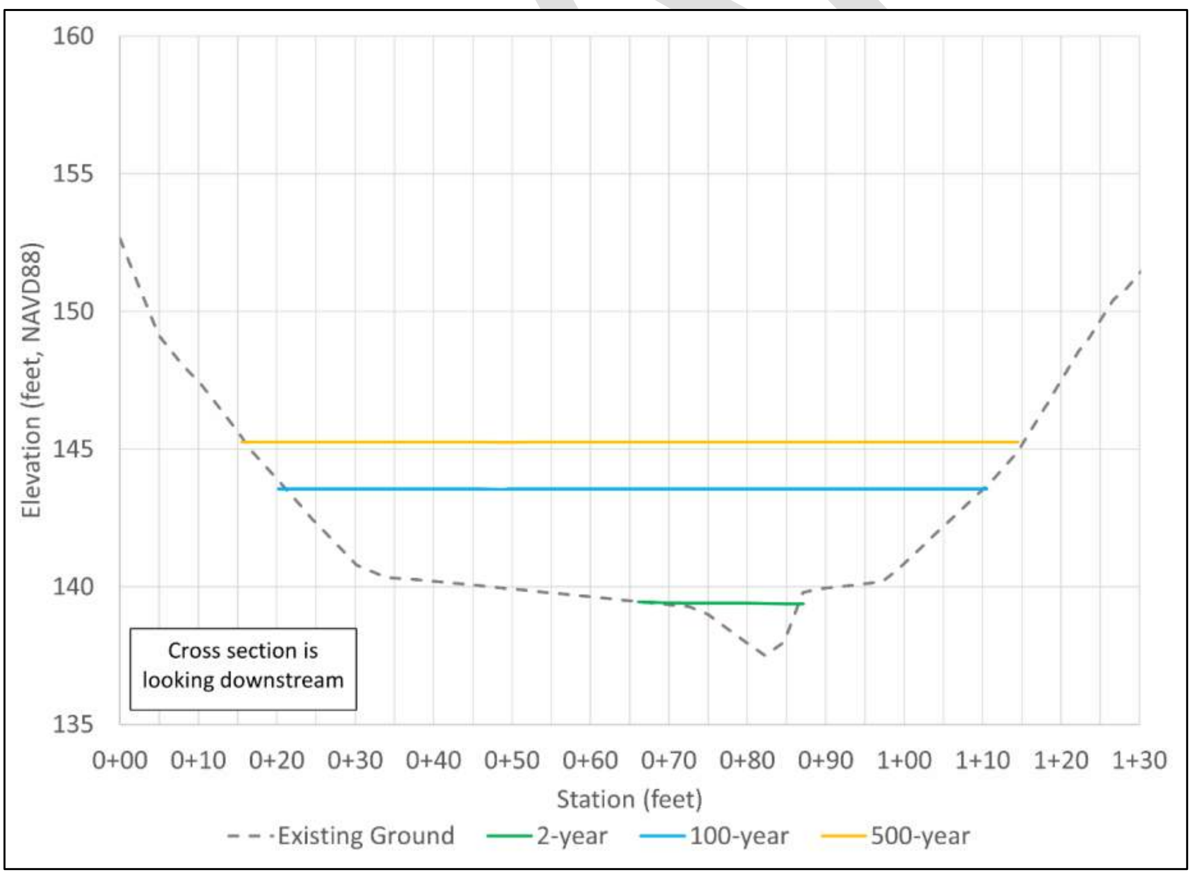

Figure 59: Typical upstream existing channel cross section (Station 7+00)

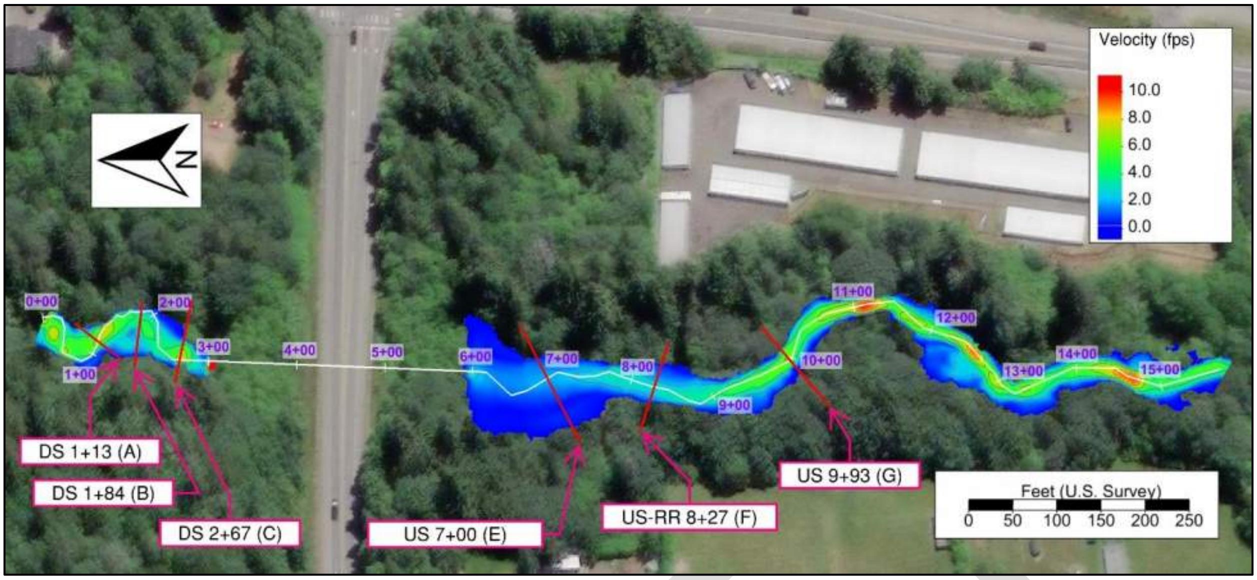

Figure 60: Existing-conditions 100-year velocity map with cross-section locations

Table 12: Existing-conditions average channel and floodplains velocities

Cross-section location	Q100 average velocities tributary scenario (ft/s)		
	LOB[a]	Main channel	ROB[a]
DS 1+13 (A)	1.2	5.6	2.8
DS 1+84 (B)	1.5	2.7	0.0
DS 2+67 (C)	4.7	6.6	3.9
Structure (D)	NA	NA	NA
US 7+00 (E)	0.4	1.5	1.1
US 8+27 (F)	1.3	2.5	1.1
US 9+93 (G)	1.2	5.4	5.0

[a] Right overbank (ROB)/left overbank (LOB) locations were approximated using modeled 2-year event water surface top widths.

5.3 Natural Conditions

The calculated FUR for the site is more than 3.0, as discussed in Section 2.7.2.1; therefore, a natural conditions analysis was performed for this site. The model approximated natural conditions by removing road fill and grading in a channel that matched the channel meander pattern upstream and downstream of the site and followed the existing channel slope. Main channel extents were approximated. The floodplain width was estimated to mimic the surveyed valley widths. Alignments connecting the valley widths upstream and downstream of the crossing were created, and the floodplain width was graded to these extents. Model results for the natural conditions hydraulic model were extracted using observation arcs in SRH-2D. Three cross sections were placed at locations that represent typical downstream conditions, and another three cross sections were placed at locations that represent typical upstream conditions. Figure 61 shows the locations of the cross sections where the model data was extracted. Note, the figure shows the existing and proposed conditions alignment for a consistent reference between figures and reported data even though the approximated natural conditions alignment includes meanders. The results extracted from the hydraulic model were processed using an Excel spreadsheet to determine average or maximum values within the main channel (determined from 2-year flood extents) as well as the LOB and ROB areas for each cross section. See Table 13 and Appendix H for the processed results from the natural conditions hydraulic model.

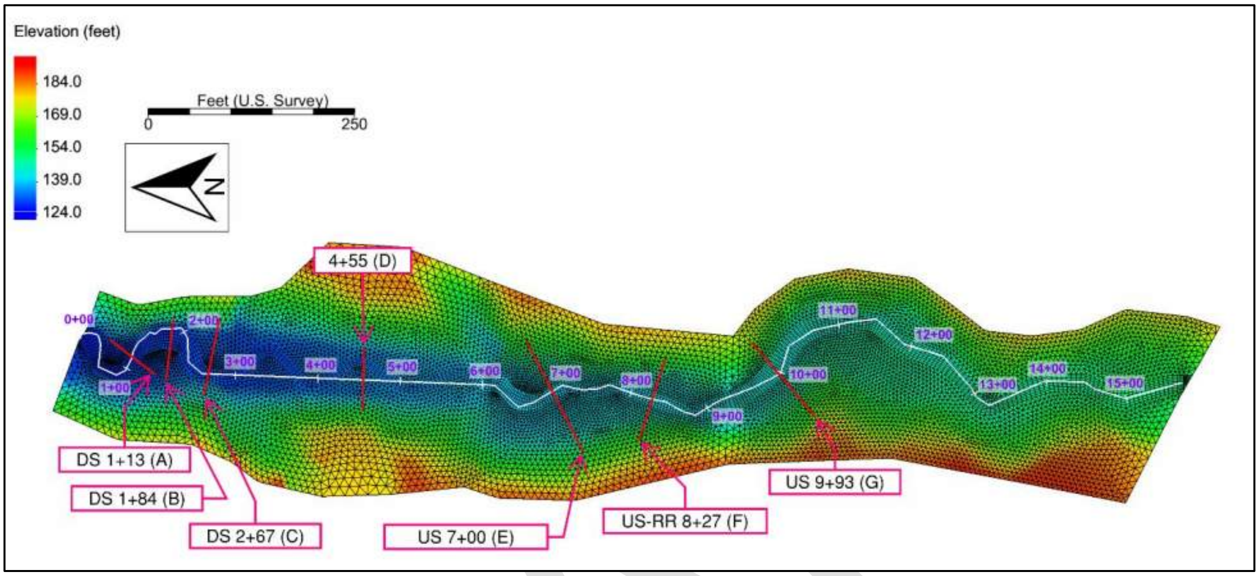

Figure 61: Locations of cross sections used for results reporting for natural conditions

Table 13: Average main channel hydraulic results for the natural conditions model

Hydraulic parameter	Cross section	2-year	100-year	500-year	Projected 2080 100-year
Average WSE (ft)	DS 1+13 (A)	128.7	130.2	130.4	130.9
	DS 1+84 (B)	129.7	131.6	131.9	132.3
	DS 2+67 (C)	130.4	131.9	132.2	132.6
	4+55 (D)	133.7	135.1	135.3	135.6
	US 7+00 (E)	139.0	140.7	140.9	141.2
	US-RR 8+27 (F)	140.1	141.9	142.1	142.5
	US 9+93 (G)	142.3	143.9	144.2	144.5
Max depth (ft)	DS 1+13 (A)	1.1	2.6	2.9	3.3
	DS 1+84 (B)	2.6	4.6	4.9	5.3
	DS 2+67 (C)	1.8	3.3	3.6	4.0
	4+55 (D)	1.2	2.7	2.9	3.2
	US 7+00 (E)	1.7	3.3	3.5	3.9
	US-RR 8+27 (F)	1.4	3.2	3.4	3.9
	US 9+93 (G)	1.5	3.2	3.5	3.9
Average velocity (ft/s)	DS 1+13 (A)	3.1	6.2	6.4	6.6
	DS 1+84 (B)	1.5	3.3	3.4	3.7
	DS 2+67 (C)	3.2	4.1	4.1	4.4
	4+55 (D)	3.5	7.0	7.1	7.2
	US 7+00 (E)	2.7	4.7	4.9	5.2
	US-RR 8+27 (F)	3.2	5.6	5.8	6.2
	US 9+93 (G)	2.1	5.9	6.2	6.8
Average shear (lb/SF)	DS 1+13 (A)	0.6	2.4	2.6	2.8
	DS 1+84 (B)	0.2	0.8	0.9	1.0
	DS 2+67 (C)	1.1	1.3	1.3	1.3
	4+55 (D)	0.9	2.1	2.2	2.2
	US 7+00 (E)	0.4	0.9	0.9	1.0
	US-RR 8+27 (F)	0.6	1.2	1.3	1.5
	US 9+93 (G)	0.3	1.3	1.4	1.6

Main channel extents were approximated using modeled 2-year event water surface top widths.

Figure 62 and Figure 63 show the natural conditions profile and the natural conditions typical cross section (at station 7+00 upstream of the crossing) for the hydraulic results analyzed.

Maximum flow depths within the modeled area ranged from 1.1 foot to 2.6 feet during the 2-year event, with a majority of the modeled reach having maximum flows depths of 1.2 foot to 1.8 feet. Velocities during the 2-year event along the stream centerline ranged from 1.5 fps to 3.5 fps in the modeled reach, with a majority of the modeled reach having velocities of 2.1 fps to 3.5 fps.

Maximum flow depths within the natural conditions model are consistent during the 100-year event. A maximum depth of 4.6 feet was modeled at station 1+84 during the 100-year event, and a typical maximum depth of 2.6 feet to 3.3 feet was modeled downstream of the approximated natural reach. Velocities during the 100-year event (see Figure 64) along the stream centerline have a maximum velocity of 7.0 fps through the approximated natural reach. A maximum water depth of 4.9 feet was modeled during the 500-year event. The maximum velocity was 7.1 fps. During the 2080 predicted 100-year event, the maximum depth was 5.3 feet and the maximum velocity was 7.2 fps.

Table 14 shows the main channel and floodplain velocity results for the 100-year, and the 2080 predicted 100-year events. Main channel velocities ranged from 3.3 fps to 7.0 fps at the selected cross sections, while the LOB and ROB velocities in the floodplain ranged from 0 fps to 4.9 fps during the 100-year event. During the 2080 predicted 100-year event, main channel velocities ranged from 3.7 fps to 7.2 fps at the selected cross sections, while the LOB and ROB velocities in the floodplain ranged from 0 fps to 6.8 fps.

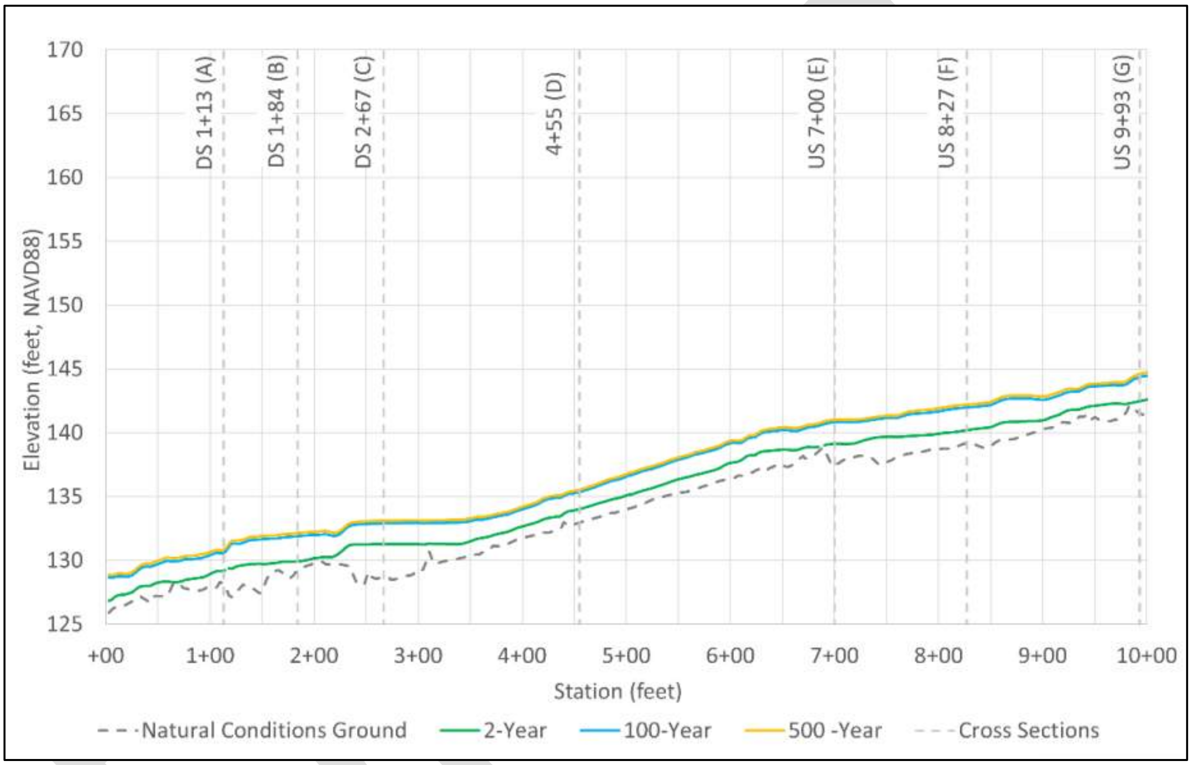

Figure 62: Natural-conditions water surface profiles

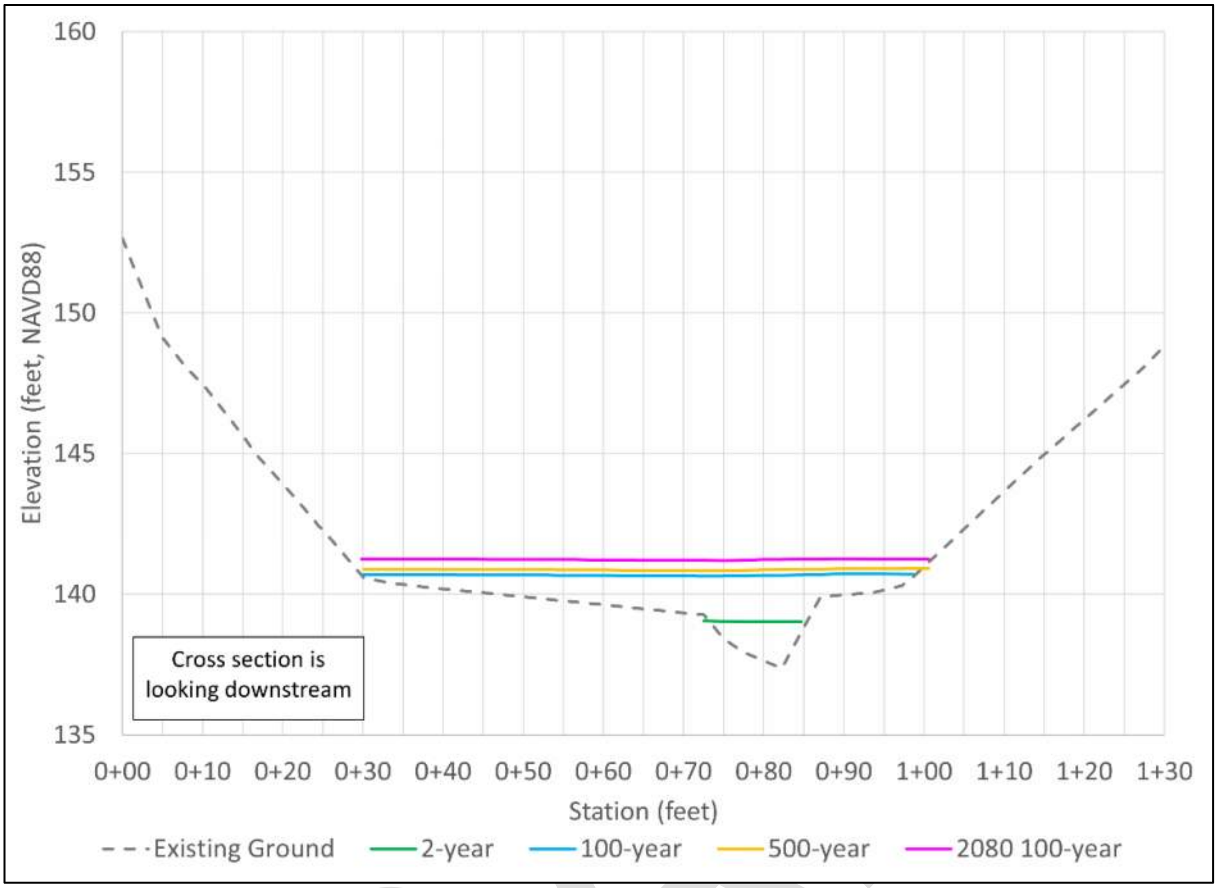

Figure 63: Typical upstream natural-conditions channel cross section (Station 7+00)

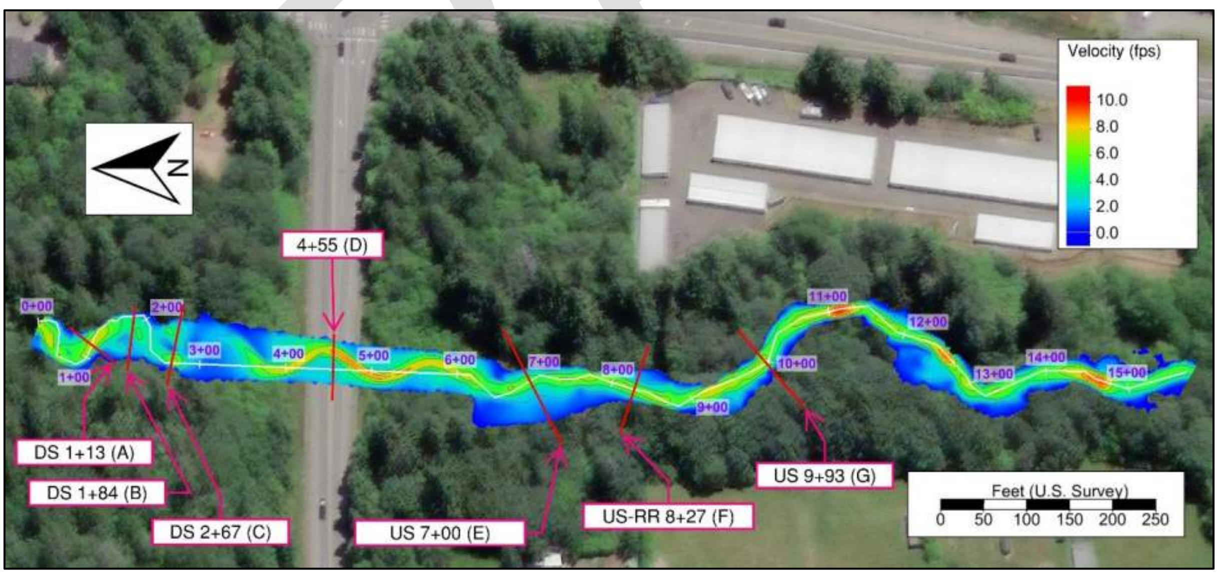

Figure 64: Natural-conditions 100-year velocity map with cross-section locations

Table 14: Natural-conditions average channel and floodplains velocities

Cross-section location	Q100 average velocities (ft/s)			2080 Q100 average velocity (ft/s)		
	LOB[a]	Main channel	ROB[a]	LOB[a]	Main channel	ROB[a]
DS 1+13 (A)	1.2	6.2	3.0	2.8	6.6	5.1
DS 1+84 (B)	1.9	3.3	0.0	3.4	3.7	0.0
DS 2+67 (C)	0.0	4.1	3.1	0.0	4.4	3.7
Structure 4+55 (D)	3.3	7.0	2.6	4.8	7.2	2.9
US 7+00 (E)	1.7	4.7	3.0	2.3	5.2	3.9
US 8+27 (F)	3.0	5.6	2.0	4.4	6.2	2.8
US 9+93 (G)	2.9	5.9	4.9	4.5	6.8	6.8

[a] Right overbank (ROB)/left overbank (LOB) locations were approximated using modeled 2-year event water surface top widths.

5.4 Proposed Conditions: 30-foot Minimum Hydraulic Width

The hydraulic width is defined as the width perpendicular to the creek beneath the proposed structure that is necessary to convey the design flow and allow for natural geomorphic processes. The hydraulic modeling assumes vertical walls at the edge of the minimum hydraulic width unless otherwise specified. See Section 4.2.2 for a description of how the minimum hydraulic width was determined.

The proposed conditions model uses the same configuration as the existing conditions model except that the SR 308 culvert was replaced with the 30-foot hydraulic opening width entered as an open-channel cut across SR 308. This approach does not use HY-8 at this crossing. Data was evaluated at the same cross sections used for existing and natural conditions (see Figure 65). Table 15 presents the calculated WSE, velocity, depth, and shear stress from the proposed conditions SRH-2D model for the 2-year, 100-year, 500-year, and predicted 2080 100-year peak flows. For additional information modeled results see the SRH-2D model results in Appendix H.

The proposed hydraulic opening width will eliminate an existing backwater condition at SR 308 and restore WSEs and depths to a more natural condition, as shown in Figure 66. The 100-year flow depth through the structure will be generally 3.1 feet, which is similar to the upstream and downstream depths, which are 3.8 and 3.5 feet, respectively. Figure 67 shows a typical cross section through the proposed crossing with WSEs corresponding to the design flows. It is anticipated that over time the channel will naturally adjust, and the depth and velocity through the crossing will match the upstream and downstream conditions.

Maximum flow depths along the length of the modeled area range from 1.1 feet to 2.7 feet during the 2-year event, with a majority of the model having maximum flows depths of 1.3 foot to 1.9 feet. Velocities during the 2-year event along the stream centerline range from 1.6 fps to 3.4 fps in the modeled reach, with a majority of the modeled reach having velocities of 2.1 fps to 3.4 fps. Maximum flow depths during the 100-year event within the model are more consistent because the backwater effect from the existing culvert would no longer be present. A maximum depth of 4.6 feet is located downstream of the crossing during the 100-year event at a location of an existing clay bank, while the model typically has maximum depths between 2.6 feet and 3.5 feet.

Velocities during the 100-year event (see Figure 68) along the stream centerline range from 3.2 fps to 6.2 fps in the modeled reach, with a majority of the modeled reach having velocities of 3.8 fps to 5.9 fps outside of the crossing and 5.7 fps within the crossing. Table 16 shows the main channel and floodplain velocity results for the 100-year event and the projected 2080 100-year event. Main channel velocities at the selected cross sections increase an average of 13.8 percent from the 100-year event to the projected 2080 100-year event, and the LOB and ROB velocities increase an average of 71.9 percent and 38.1 percent, respectively. See Table 16 for proposed-conditions average channel and floodplains velocities for more details.

Shear stresses are consistently lower through the proposed reach than immediately downstream and are similar to the shear stresses immediately upstream of the proposed crossing during the 2-year, 100-year, 2080 100-year, and 500-year events. This is because the roughness values just upstream and downstream of the structure are higher than through the structure to account for the LWM that will be placed. The average main channel shear stresses through the crossing match the average shear stresses measured at the seven cross section locations reported in Table 15 for all flows analyzed.

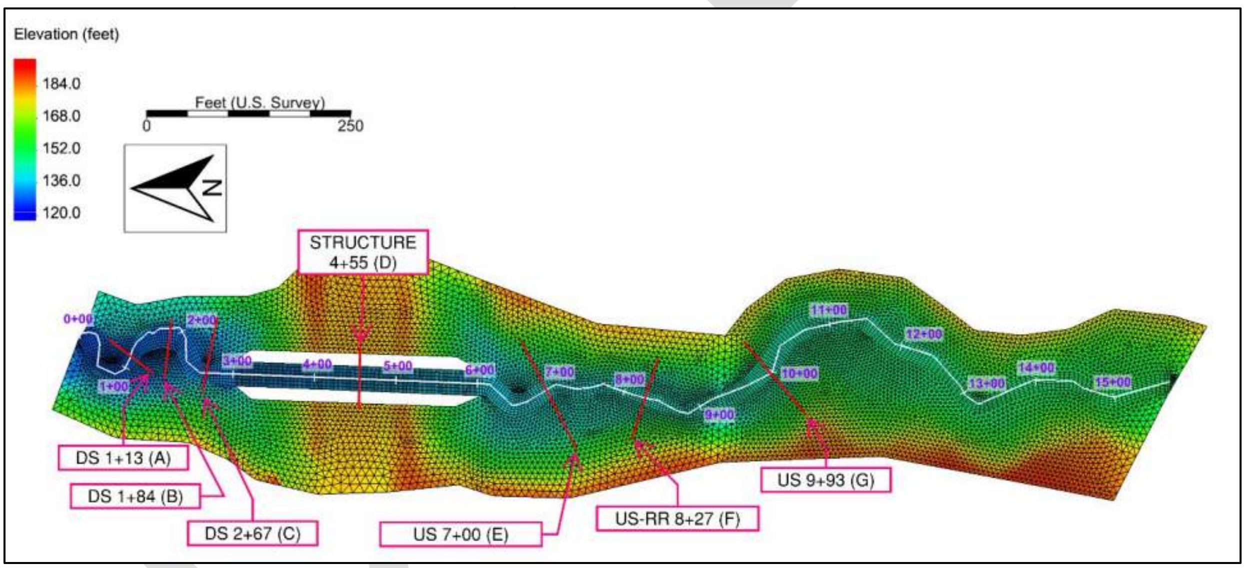

Figure 65: Locations of cross sections on proposed alignment used for results reporting

Table 15: Average main channel hydraulic results for proposed conditions

Hydraulic parameter	Cross section	2-year	100-year	500-year	Projected 2080 100-year
Average WSE (ft)	DS 1+13 (A)	128.7	130.1	130.4	130.9
	DS 1+84 (B)	129.8	131.6	131.8	132.3
	DS 2+67 (C)	130.8	132.4	132.6	133.0
	Structure 4+55 (D)	133.6	135.2	135.5	135.9
	US 7+00 (E)	138.3	140.2	140.4	140.8
	US-RR 8+27 (F)	140.0	141.8	142.1	142.5
	US 9+93 (G)	142.3	143.9	144.2	144.5
Max depth (ft)	DS 1+13 (A)	1.1	2.6	2.9	3.3
	DS 1+84 (B)	2.7	4.6	4.9	5.3
	DS 2+67 (C)	1.8	3.5	3.7	4.2
	Structure 4+55 (D)	1.5	3.1	3.4	3.8
	US 7+00 (E)	1.9	3.8	4.1	4.5
	US-RR 8+27 (F)	1.3	3.1	3.4	3.8
	US 9+93 (G)	1.5	3.2	3.5	3.9
Average velocity (ft/s)	DS 1+13 (A)	3.2	6.2	6.3	6.5
	DS 1+84 (B)	1.6	3.2	3.4	3.6
	DS 2+67 (C)	1.6	4.6	5.0	5.6
	Structure 4+55 (D)	3.3	5.7	6.0	6.5
	US 7+00 (E)	1.9	3.8	4.0	4.4
	US-RR 8+27 (F)	3.4	5.7	5.9	6.4
	US 9+93 (G)	2.1	5.9	6.2	6.8
Average shear (lb/SF)	DS 1+13 (A)	0.7	2.6	2.7	2.9
	DS 1+84 (B)	0.2	0.7	0.7	0.8
	DS 2+67 (C)	1.1	3.9	4.4	5.3
	Structure 4+55 (D)	1.0	2.3	2.5	2.8
	US 7+00 (E)	1.0	2.5	2.7	3.1
	US-RR 8+27 (F)	0.6	1.3	1.4	1.6
	US 9+93 (G)	0.3	1.3	1.4	1.6

Main channel extents were approximated using modeled 2-year event water surface top widths.

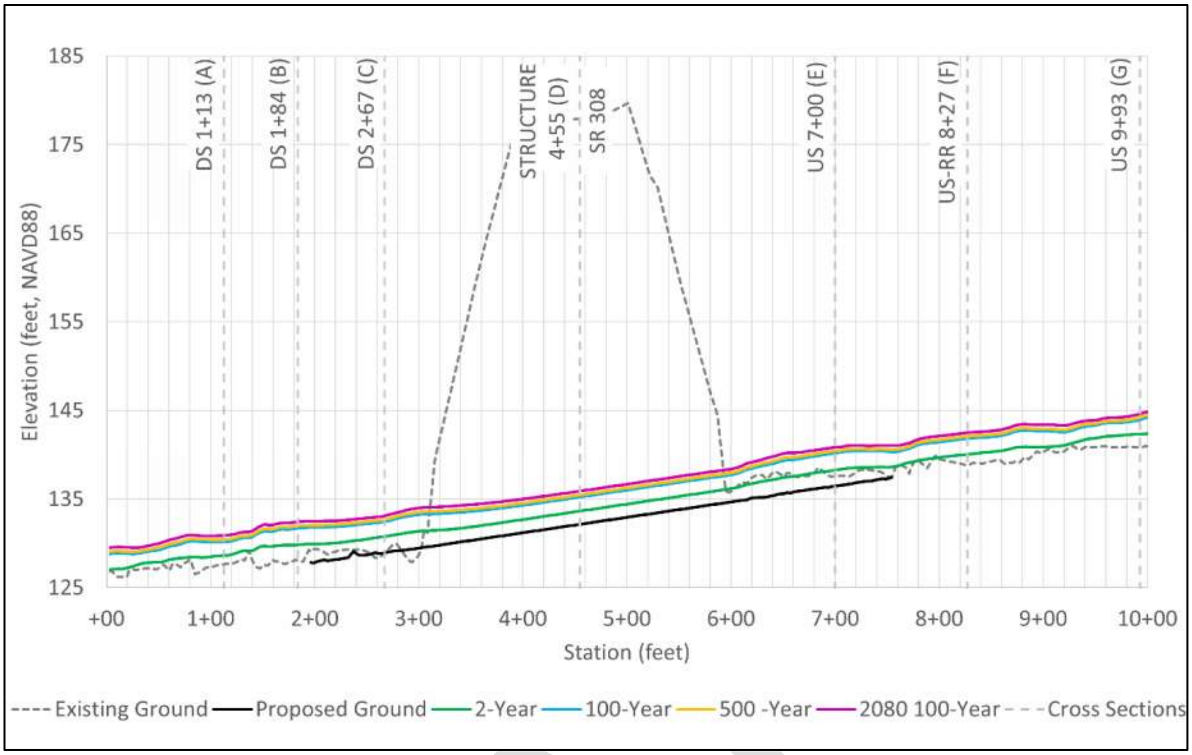

Figure 66: Proposed-conditions water surface profiles

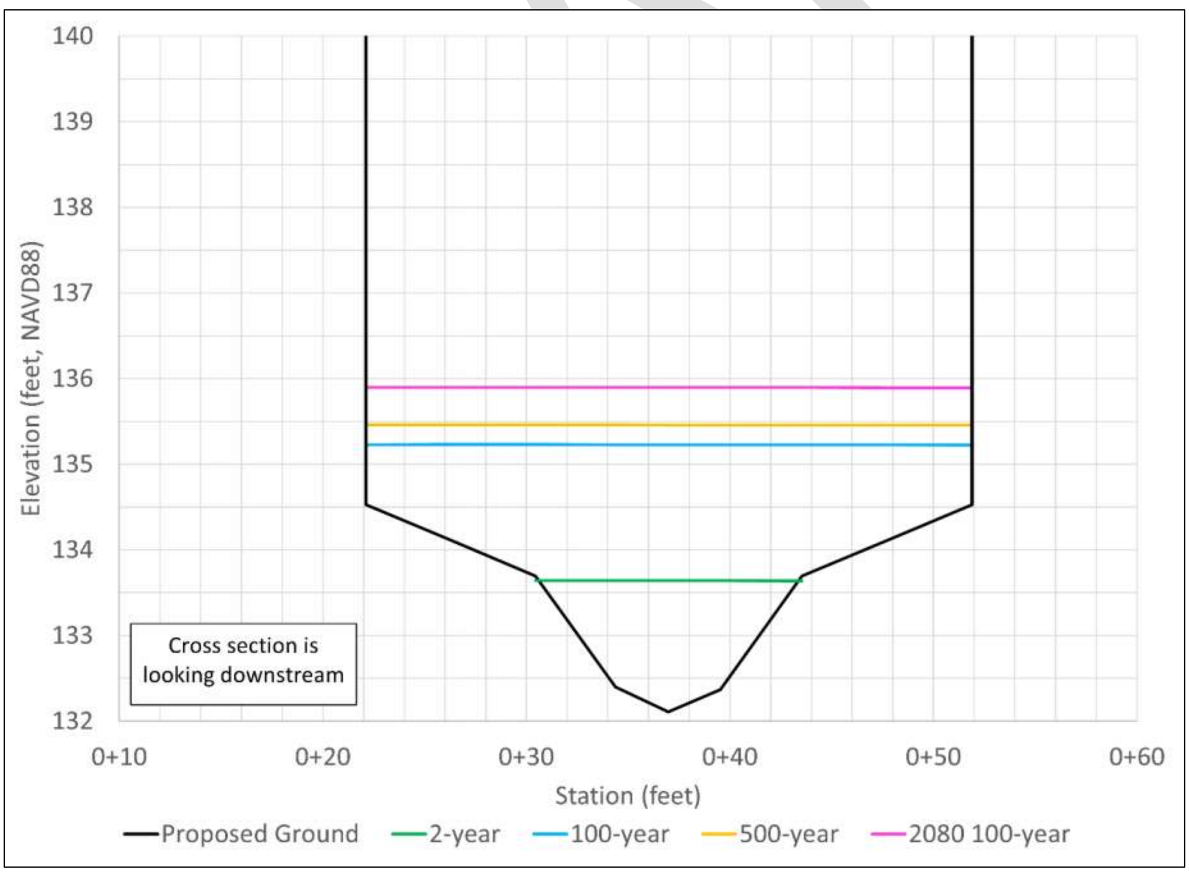

Figure 67: Typical section through proposed structure (Station 4+55)

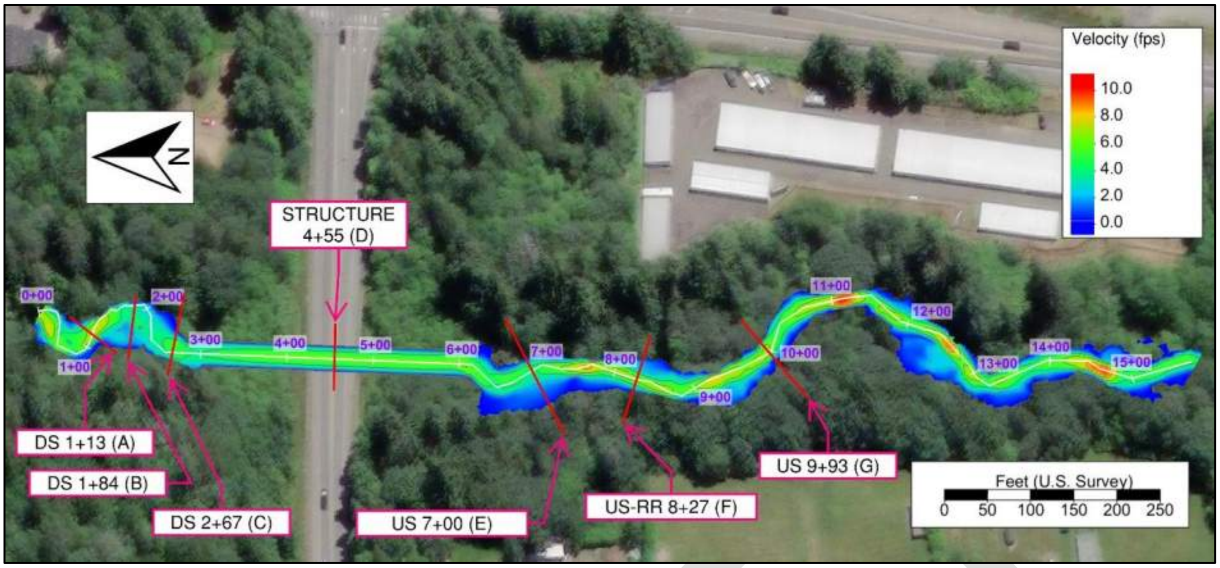

Figure 68: Proposed-conditions 100-year velocity map

Table 16: Proposed-conditions average channel and floodplains velocities

Cross-section location	Q100 average velocities (ft/s)			2080 Q100 average velocity (ft/s)		
	LOB[a]	Main channel	ROB[a]	LOB[a]	Main channel	ROB[a]
DS 1+13 (A)	1.2	6.2	3.4	2.9	6.5	5.3
DS 1+84 (B)	1.8	3.2	0.0	3.3	3.6	0.0
DS 2+67 (C)	2.1	4.6	2.9	4.2	5.6	4.0
Structure 4+55 (D)	4.5	5.7	4.5	5.5	6.5	5.5
US 7+00 (E)	1.4	3.8	2.4	2.2	4.4	3.3
US-RR 8+27 (F)	3.2	5.7	2.2	4.6	6.4	3.0
US 9+93 (G)	2.9	5.9	4.9	4.5	6.8	6.8

[a] Right overbank (ROB)/left overbank (LOB) locations were approximated using modeled 2-year event water surface top widths.

6 Floodplain Evaluation

This project is not within a FEMA special flood hazard area (SFHA). See Appendix A for the Flood Insurance Rate Map (FIRM). The existing-project and expected proposed-project conditions were evaluated to determine whether the project would cause a change in flood risk.

6.1 Water Surface Elevations

With the proposed project, WSE changes will be limited to the immediate vicinity of the crossing. The proposed project will eliminate backwater conditions at SR 308, so that the water surface elevation immediately upstream will be reduced by the proposed crossing. The existing and proposed water surface profiles will converge at station 9+88 due to the larger crossing and regrading of the channel. The downstream WSE will increase slightly immediately downstream of the culvert as the hydraulics of this crossing are restored to more natural conditions (see Figure 69). WSE increases downstream of the crossing are due to reductions in outlet velocity and are not a result of fill from the project. These increases will be minor (see Figure 70). There are no risks to properties or infrastructure. A flood risk assessment will be developed during later stages of the design.

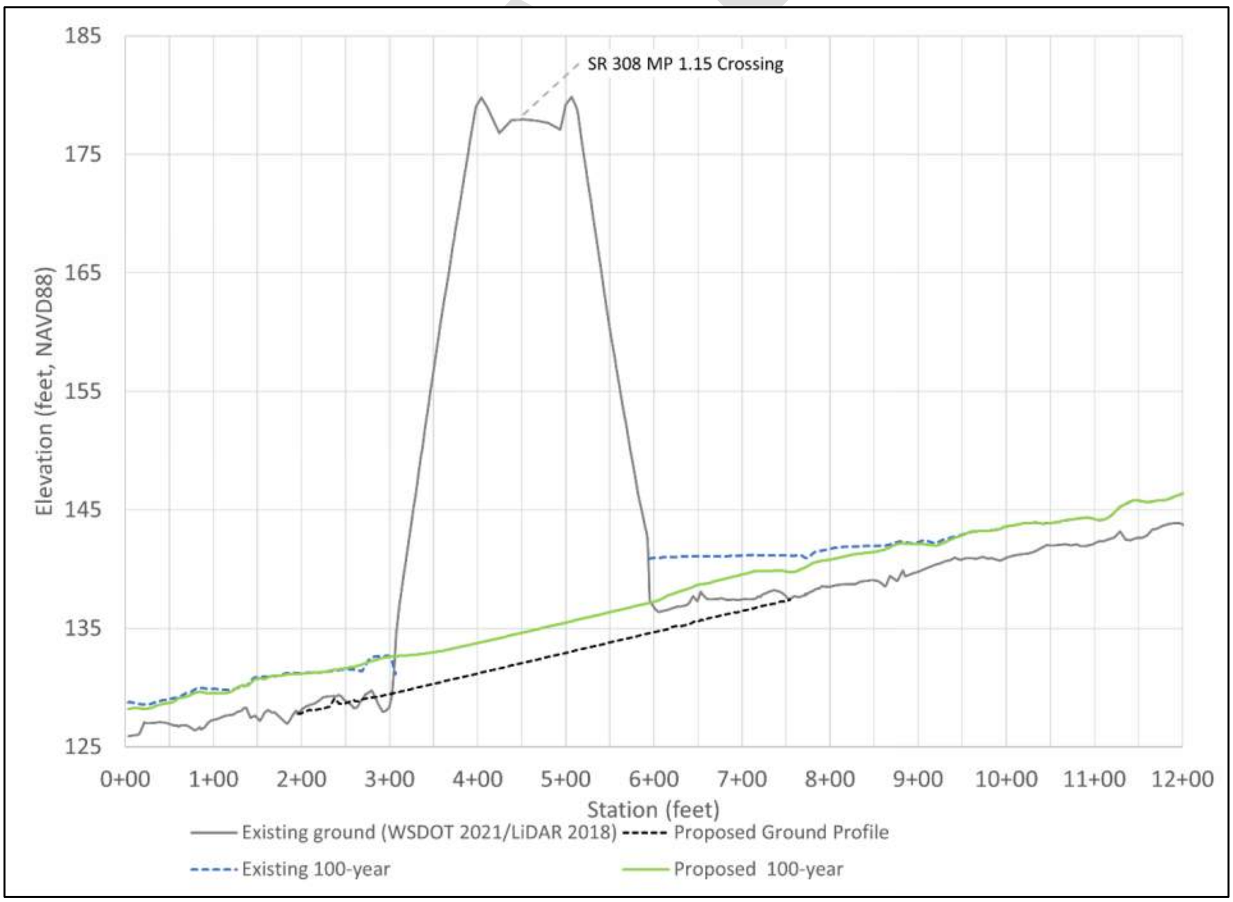

Figure 69: Existing- and proposed-conditions 100-year water surface profile comparison along proposed alignment

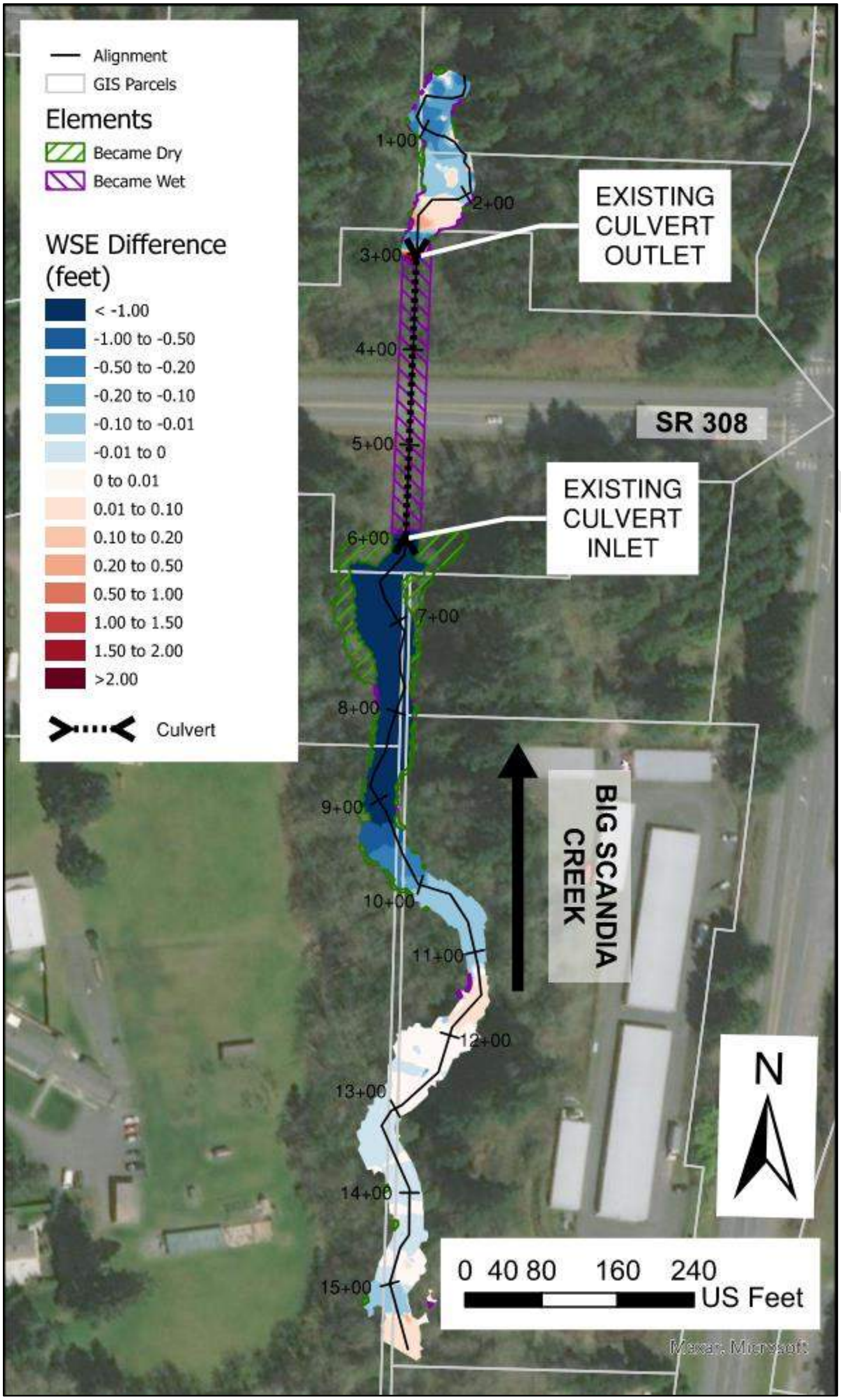

Figure 70: 100-year WSE change from existing to proposed conditions

7 Preliminary Scour Analysis

For this preliminary phase of the project, the risk for lateral migration, potential for long-term degradation, and evaluation of preliminary total scour are based on available data, including but not limited to hydraulic modeling and preliminary geotechnical data. This evaluation is considered preliminary and is not to be taken as a final recommendation. The geotechnical scoping memo provided by WSDOT dated September 7, 2022, contained three soil borings used to inform this section.

Using the results of the hydraulic analysis (Section 5.4), based on the recommended minimum hydraulic opening (30 feet), and considering the potential for lateral channel migration, preliminary scour calculations for the scour design flood and scour check flood were performed following the procedures outlined in Evaluating Scour at Bridges, HEC No. 18 (Arneson et al. 2012).

Scour components considered in the analysis include:

- Long-term degradation
- Contraction scour
- Local scour

In addition to the three scour components listed above, the potential for lateral migration was assessed to evaluate total scour at the proposed highway infrastructure. These various scour components will be discussed in the following sections.

Scour Analysis was evaluated using the 2-, 10- 25-, 50-, 100-, 500-, and projected 2080 100-year flow events. Based on the analysis of scour depths (see Appendix K) and since the 500-year flow event (297 cfs) is smaller than 2080 100-year flow event (402 cfs), the scour design flood as well as the scour check flood were evaluated to be the 2080 100-year event. It was assumed without contacting WSDOT HQ Hydraulics, that the design of the proposed structure should account for the potential scour at the projected 2080 100-year flow event. A more refined analysis will be completed during the final hydraulic design.

7.1 Lateral Migration

The geotechnical scoping memo for the site included information on three soil borings along the alignment of the existing crossing. The soil borings showed in-situ coarse-grained glacial deposits (ESU 4) containing organic soil, very loose silty sand with logs and roots. The soil borings confirmed the geologic and soil mapping data presented in Section 2.3. The geotechnical scoping memo determined that the soils are cohesionless and have high (II) to medium (III) HEC-18 erodibility. Therefore, there is risk of lateral migration on Big Scandia Creek. The confined nature of the channel and tall valley walls will restrict large scale lateral migration, but the dynamic physical processes resulting from natural and constructed channel forcing elements, such as meander bars, will encourage small scale lateral migration of the main channel within bottom of the current valley. Staff from WDFW and Suquamish tribal representatives expressed some concern about channel meander through the valley floor. To mitigate this risk, the channel was realigned to shift the crossing to a more central location within the historical valley (see Section 5.4 for the proposed design). The realignment balances the risk of lateral migration and the loss of channel length.

The upstream and downstream portions of Big Scandia Creek appear to have ample sediment supply because no active vertical incision was observed upstream of the culvert (See Section 2.7.4). The risk of lateral migration of Big Scandia Creek is minimal due to low flows and the confines of the valley on either side of the creek, as mentioned in Section 2.7.5.The watershed is in a zone of frequent landslides. Future slides within the watershed will provide additional sediment to the stream system. The ample sediment supply, in combination with the flattening longitudinal profile downstream of the crossing, will create the potential for aggradation at the crossing, as described in Section 2.7.4. Potential aggradation increases the chances for lateral migration.

Since lateral migration of the stream is possible, local scour at the abutments will be estimated for flows which do not currently engage with the abutments. Additionally, design of scour countermeasures in and around the inlets should also consider the possibility of lateral migration of this stream.

Scour countermeasures can mitigate all or some components of total scour at walls and roadway embankments through coordination with the region design team and approval by hydraulics, bridge, and the geotechnical offices. Total scour for structure foundations shall not rely on the scour countermeasures.

7.2 Long-term Degradation of the Channel Bed

The proposed channel alignment and slope closely mimic the existing conditions within the project limits, but a flattening in the channel slope just downstream of the proposed channel grading creates a medium potential for long-term aggradation. Section 2.7.4 discusses the vertical channel stability. Base-level controls such as bedrock, non-erodible material, or nick points were not identified in the field nor in any supporting documentation, such as the geotechnical scoping memo. The potential for long-term degradation was based upon suvery and LiDAR data used to construct longitudinal profiles of the stream. Long-term degradation will be further quantified in the Final Hydraulic Design report. Based on the available data, approximately 0.8 feet of potential long-term degradation is expected at equilibrium slope. (Figure 71).

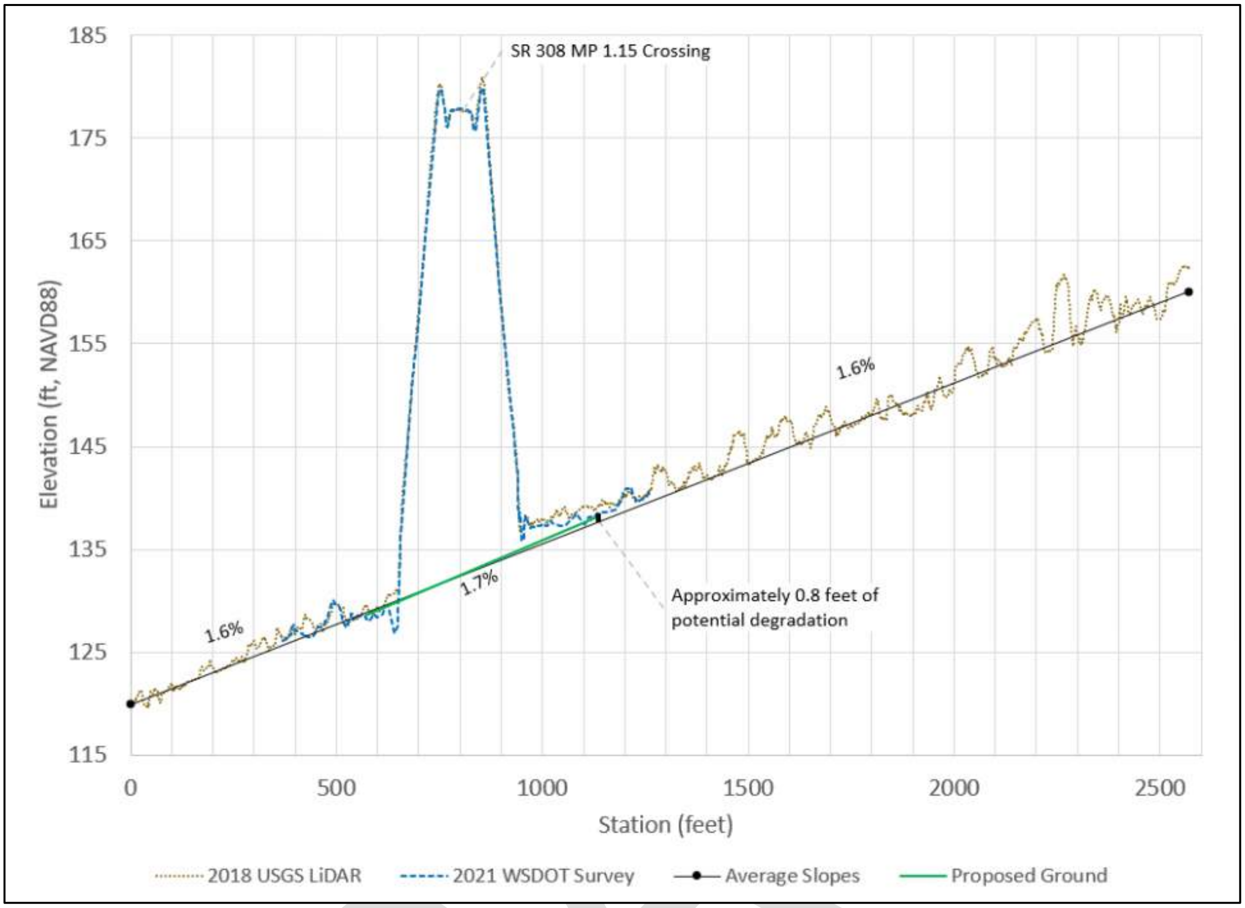

Figure 71: Potential long-term degradation at the proposed structure upstream face

7.3 Contraction Scour

The 2-year, 10-year, 25-year, 50-year, 100-year, 2080 100-year, and 500-year events were evaluated for contraction scour. Critical velocity was calculated for each recurrence interval with a proposed median sediment size (D_{50}) of 1.2 inches (see Section 4.3.1). The existing D_{50} is 0.9 inches (see Section 2.7.3). The critical velocity index evaluation, including shear stress and velocity results of the existing and proposed hydraulic models contained in Appendix H and Appendix K, shows clear water scour conditions during all flows. Flow events less than or equal to the 500-year event produce clear water conditions throughout the channel crossing. The 2080 100-year flow event indicates some live-bed and some clear-water conditions along the channel. However, for areas about 100-feet upstream of the crossing inlet, the CVI values are around 0.7 indicating distinct clear-water conditions. So, it can be assumed that sediment at the inlet will drop down in this section and the scour within the crossing will be in clear-water regime.

Therefore, clear water conditions were assumed to be dominant within the main channel for all flow events, including the 2080 100-year flow. See Appendix K for critical velocity figures. The approach section was drawn based on the contraction of velocity vectors. Bank lines were drawn based on topography, where bulk of flow occurs within the main channel.

Although the scour condition was assumed to be clear-water, both clear-water and live-bed scour conditions were evaluated in the Hydraulic Toolbox. HEC-18 directs the designer to select the lesser of the scour depths between clear-bed and live-bed scour conditions. The contraction scour calculation results for clear-water conditions are 0-feet for all flow events.

7.4 Local Scour

Local scour includes scour at bridge abutments, piers, and bends. A preliminary analysis of local scour was performed using the Federal Highway Administration's Hydraulic Toolbox Version 5.1.4 computer program (FHWA 2021).

7.4.1 Pier Scour

The crossing is not anticipated to have piers and therefore pier scour was not calculated.

7.4.2 Abutment Scour

Abutment scour was estimated using the National Cooperative Highway Research Program (NCHRP) 24-20 approach for the scour design flood and scour check flood. The 2-year, 10-year, 25-year, 50-year, 100-year, 500-year and 2080 100-year events were evaluated for abutment scour (Appendix K). The abutment scour calculated using the NCHRP methodology includes contraction scour; therefore, contraction scour should not be added to total scour.

The hydraulic model developed in SMS (see Section 5) was used to create bridge scour coverages for each recurrence interval and these values were exported as inputs to the Hydraulic toolbox (FHWA 2021), which was used to calculate abutment scour. Appendix K provides the location of the approach section arc, contraction section arc, bank arcs and abutment arcs used to calculate abutment scour. Since only the minimum hydraulic opening has been determined, the abutments are assumed to be vertical wall abutments. Scour condition A was used for calculations since the scour conditions are at the face of the assumed abutment walls.

Although lateral migration is minimal for this channel a conservative estimate of abutment scour was estimated by using the water depth at the thalweg of the channel. The depth of abutment scour, when applied to the thalweg elevation of the proposed channel was calculated to be 1.4 feet for the 2080 100-year flood. The abutment scour depth results are presented in Table 17. See Appendix K for preliminary scour results.

7.4.3 Bend Scour

Bend scour was not quantified at this crossing given the lack of anticipated bends in the vicinity of the crossing.

7.5 Total Scour

Preliminary scour calculations predict approximately 2.2 feet of total scour within the structure (Table 17). Calculated total depths of scour for the scour design flood and scour check flood at the proposed Big Scandia Creek crossing as shown in the plans dated DECEMBER 22, 2022 are provided in Table 17. HQ Hydraulics recommends that each infrastructure component be designed to account for the depths of scour provided in Table 17.

Abutment scour using the NCHRP methodology includes contraction scour. Therefore, contraction scour was not added to total scour.

Table 17: Scour analysis summary

Calculated scour components and total scour for SR 308 MP 1.15 Big Scandia Creek		
	SR 308 structure	
	Scour design flood (2080 100-year event)	Scour check flood (2080 100-year event)
Long-term degradation (ft)	0.8	0.8
Contraction scour (ft)	0.0	0.0
Local scour (ft)[a]		
Abutment scour depth relative to thalweg (ft)	1.4	1.4
Total depth of scour (ft) [a]	**2.2**	**2.2**

[a] Depths are relative to the thalweg elevation

8 Scour Countermeasures

Scour countermeasures are not anticipated to be required because of the low likelihood of the channel migrating laterally beyond the MHO, low calculated scour amounts (approx. 2- feet) relative to the 2-foot-minimum proposed streambed sediment depth, and the potential for aggradation. If scour countermeasures are needed, they may not encroach within the minimum hydraulic opening. The recommendation in Section 4.2.4 to utilize a taller structure, headwalls, or wingwalls to reduce structure length may reduce the extent of scour countermeasures if they are needed. If LWM is placed within the structure at future design phases, scour countermeasures will be needed to protect against scour near the LWM pieces. At the time this report is written, there are no properties around the inlet area of the crossing which could cause right-of -way issues with construction of scour countermeasures.

9 Summary

Table 18 presents a summary of the results of this Preliminary Hydraulic Design Report.

Table 18: Report summary

Stream crossing category	Element	Value	Report location
Habitat gain	Total length	26,581 linear feet	2.1Site Description
Bankfull width	Reference reach found?	Yes	2.7.1 Reference Reach Selection
	Design BFW	13.0 feet	2.7.2 Channel Geometry
	Concurrence BFW	13.0 feet	2.7.2 Channel Geometry
Floodplain utilization ratio (FUR)	Flood-prone width	45.0 feet	2.7.2.1 Floodplain Utilization Ratio
	Average FUR	2.8 US/3.7 DS	2.7.2.1 Floodplain Utilization Ratio
Channel morphology	Existing	See link	2.7.2 Channel Geometry
	Proposed	See link	2.7.2 Channel Geometry
Hydrology/design flows	100-year flow	247.6 cfs	3 Hydrology and Peak Flow Estimates
	2080 100-year flow	401.6 cfs	3 Hydrology and Peak Flow Estimates
	2080 100-year used for design	Yes	3 Hydrology and Peak Flow Estimates
	Dry channel in summer	No	3 Hydrology and Peak Flow Estimates
Channel geometry	Existing	See link	2.7.2 Channel Geometry
	Proposed	See link	4.1.1 Channel Planform and Shape
Channel slope/gradient	Existing culvert	2.1%	2.6.2 Existing Conditions
	Reference reach	1.5%	2.7.1 Reference Reach Selection
	Proposed	1.7%	4.1.3 Channel Gradient
Hydraulic width	Existing	6.0 feet	2.6.2 Existing Conditions
	Proposed	30.0 feet	4.2.2 Hydraulic Width
	Added for climate resilience	No	4.2.2 Hydraulic Width
Vertical clearance	Required freeboard	3.0 feet	4.2.3 Vertical Clearance
	Required freeboard applied to 100-year or 2080 100-year	2080 100 year	4.2.3 Vertical Clearance
	Maintenance clearance	Recommended 6 feet	4.2.3 Vertical Clearance
	Low chord elevation	See link	4.2.3 Vertical Clearance
Crossing length	Existing	292 feet	2.6.2 Existing Conditions
	Proposed	292 feet	4.2.4 Hydraulic Length
Structure type	Recommendation	No	4.2.6 Structure Type
	Type	Culvert or Bridge	4.2.6 Structure Type
Substrate	Existing	See link	2.7.3 Sediment
	Proposed	See link	4.3.1 Bed Material
	Coarser than existing?	No	4.3.1 Bed Material

Stream crossing category	Element	Value	Report location
Channel complexity	LWM for bank stability	No	4.3.2 Channel Complexity
	LWM for habitat	Yes	4.3.2 Channel Complexity
	LWM within structure	No	4.3.2 Channel Complexity
	Meander bars	Culvert Concept: 8 Bridge Concept: 2	4.3.2 Channel Complexity
	Boulder clusters	0	4.3.2 Channel Complexity
	Coarse bands	0	4.3.2 Channel Complexity
Floodplain continuity	FEMA mapped floodplain	No	6 Floodplain Evaluation
	Lateral migration	No	2.7.5 Channel Migration
	Floodplain changes?	Yes	6 Floodplain Evaluation
Scour	Analysis	See link	7 Preliminary Scour Analysis
	Scour countermeasures	Determined at FHD	8 Scour Countermeasures
Channel degradation	Potential?	Yes	7.2 Long-term Degradation of the Channel Bed
Channel degradation	Allowed?	Yes	7.2 Long-term Degradation of the Channel Bed

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Appendices

Appendix A: FEMA Floodplain Map

Appendix B: Hydraulic Field Report Form

Appendix C: Streambed Material Sizing Calculations

Appendix D: Stream Plan Sheets, Profile, Details

Appendix E: Manning's Calculations

Appendix F: Large Woody Material Calculations

Appendix G: Future Projections for Climate-Adapted Culvert Design

Appendix H: SRH-2D Model Results

Appendix I: SRH-2D Model Stability and Continuity

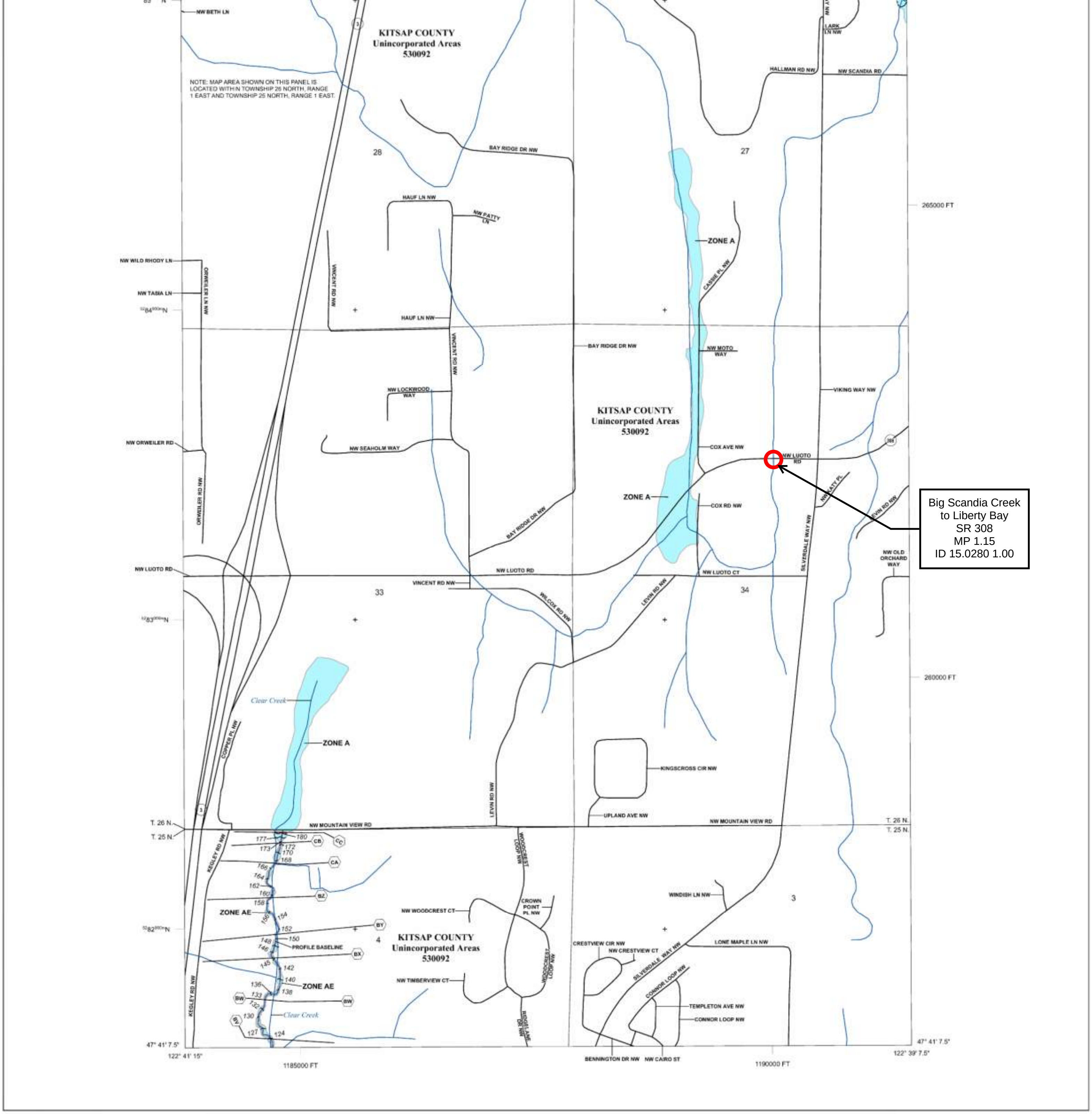
Appendix J: Reach Assessment

Appendix K: Scour Calculations (PRELIMINARY)

Appendix L: Floodplain Analysis (FHD ONLY)

Appendix M: Scour Countermeasure Calculations (FHD ONLY)

Appendix A: FEMA Floodplain Map



FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR ZONE DESCRIPTIONS AND INDEX MAP

THE INFORMATION DEPICTED ON THIS MAP AND SUPPORTING DOCUMENTATION ARE ALSO AVAILABLE IN DIGITAL FORMAT AT

HTTP://MSC.FEMA.GOV

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) *Zone A,V, A99*
	With BFE or Depth *Zone AE, AO, AH, VE, AR*
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
	Future Conditions 1% Annual Chance Flood Hazard *Zone X*
	Area with Reduced Flood Risk due to Levee See Notes. *Zone X*
OTHER AREAS	NO SCREEN Areas Determined to be Outside the 0.2% Annual Chance Floodplain *Zone X*
	Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer
	Accredited or Provisionally Accredited Levee, Dike, or Floodwall
	Non-accredited Levee, Dike, or Floodwall
	(E) 18.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation (BFE)

NOTES TO USERS

For information and questions about this map, available products associated with this FIRM including historic versions of this FIRM, how to order products or the National Flood Insurance Program in general, please call the FEMA Map Information eXchange at 1-877-FEMA-MAP (1-877-336-2627) or visit the FEMA Map Service Center website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the website. Users may determine the current map date for each FIRM panel by visiting the FEMA Map Service Center website or by calling the FEMA Map Information eXchange.

Communities annexing land on adjacent FIRM panels must obtain a current copy of the adjacent panel as well as the current FIRM index. These may be ordered directly from the Map Service Center at the number listed above.

For community and countywide map dates refer to the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in the community, contact your Insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

Base map information shown on this FIRM was provided in digital format by Washington State GIS, Kitsap County GIS and Kitsap County Auditor and Elections.

SCALE

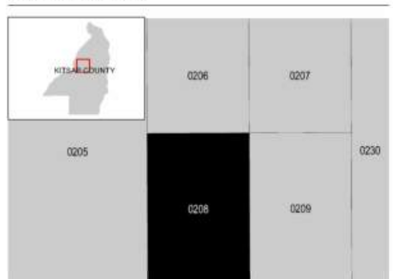
Map Projection:
NAD 1983 UTM Zone 10N;
Western Hemisphere; Vertical Datum: NAVD 88

1 inch = 500 feet 1:6,000

0 500 1,000 2,000 Feet

0 125 250 500 Meters

PANEL LOCATOR



FEMA

National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM
FLOOD INSURANCE RATE MAP

KITSAP COUNTY, WASHINGTON
AND INCORPORATED AREAS

PANEL **208** OF **525**

Panel Contains:

COMMUNITY	NUMBER	PANEL	SUFFIX
KITSAP COUNTY	530092	0208	F

Appendix B: Hydraulic Field Report Form

WSDOT	Hydraulics Field Report	Project Number: Y-12554 - Task Order AC
Hydraulics Section	Project Name: Olympic Region GEC	Date: 11/29/2021
	Project Office: WSDOT HQ Hydraulics Office - Olympic Region	Time of Arrival: 12:00 pm
	Stream Name: Big Scandia Creek	Time of Departure: 1:20 pm
WDFW ID Number: 15.0280 1.00	Tributary to: Liberty Bay - Puget Sound	Weather: Partly Sunny, 55° F
State Route/MP: SR 308 MP 1.15	Township/Range/Section/ ¼ Section: Township 26 North, Range 01 East, Section 35	Prepared By: Atalia Raskin
County: Kitsap	Purpose of Site Visit: Site Visit 2- Stream Assessment, Project Constraints	WRIA: 15.0280

Meeting Location:
15244 Silverdale Way NW, Poulsbo, WA 98370

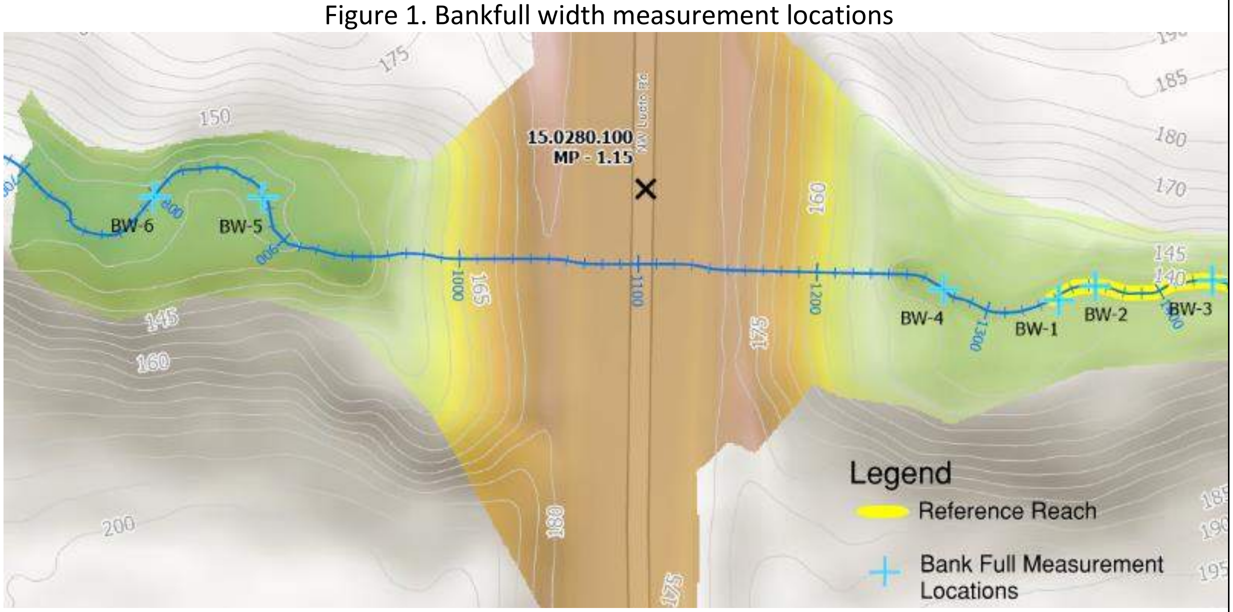
Attendance List:

Name	Organization	Role
Atalia Raskin	David Evans and Associates, Inc.	Lead PHD Author
Josh Owens	David Evans and Associates, Inc.	Geomorphologist
Micco Emeson	David Evans and Associates, Inc.	Engineer
Mike Rice	David Evans and Associates, Inc.	Engineer
Rachel Krulc	David Evans and Associates, Inc.	Junior Engineer
Ryan Barkie	David Evans and Associates, Inc.	Junior Engineer

Bankfull Width:

Four bankfull width (BFW) measurements were taken upstream of the existing culvert (BFW-1, BFW-2, BFW-3, and BFW-4), three of these are within the within the reference reach (BFW-1, BFW-2, and BFW-3). The average of these measurements is 12.5 feet. Two additional bankfull widths (BFW-5 & BFW-6) were measured downstream of the existing culvert. See Figure 1 for bankfull width measurement locations.

Figure 1. Bankfull width measurement locations



BFW-1 was measured within the reference reach 118 feet upstream of the SR 308 culvert (Figure 2). The measured BFW was 12.5 feet.

Figure 2. BFW-1 measurement

BFW-2 was measured within the reference reach 140 feet upstream of the SR 308 culvert (Figure 3). The measured BFW was 13 feet.

Figure 3. BFW-2 measurement

BFW-3 was measured within the reference reach 200 feet upstream of the SR 308 culvert (Figure 4). The measured BFW was 12 feet.

Figure 4. BFW-3 measurement

BFW-4 was measured within the reference reach 50 feet upstream of the SR 308 culvert (Figure 5). The measured BFW was 10 feet. This culvert was found to be too close to the existing culvert and removed consideration.

Figure 5. BFW-4 measurement

BFW-5 was measured 100 feet downstream of the SR 308 culvert outside of the reference reach. The width was measured downstream of a large plunge pool at the culvert outlet and upstream of a channel bend restricted by natural clay deposits (Figure 6). The measured BFW was 22 feet.

Figure 6. BFW-5 measurement

BFW-6 was measured 130 feet downstream of the SR 308 culvert outside of the reference reach. The width was measured downstream of a channel bend restricted by natural clay deposits (Figure 7). The measured BFW was 13 feet.

Figure 7. BFW-6 measurement

Reference Reach:

The reference reach is a 130-foot segment of stream that begins approximately 85 feet upstream of the culvert inlet, extending to a distance approximately 215 feet upstream of the culvert inlet. There was no evidence of scour and minor deposition at the upstream end of the culvert indicating that the culvert is not capacity limited and there is little upstream hydraulic influence caused by the culvert (Figure 8).

Figure 8. Deposition at culvert inlet

The channel downstream of the culvert was not suitable for a reference reach because there was evidence of scour, and bank erosion directly downstream of the culvert for about 30 feet (Figure 9). The channel appears to take a more natural form further downstream. A natural clay deposit restricts the channel approximately 160 feet downstream of the channel (Figure 10).


Figure 9. Scour and erosion at culvert outlet

Figure 10. Clay bank

The reference reach is moderately confined, having steep hillslopes on either side of a narrow overbank area of the channel. At the upstream end of the reference reach the channel becomes more confined with limited overbank area. The flat overbank width varies in length as the channel meanders through the 70 feet overbank area. The overbank areas are readily accessible during flood events. The reference reach channel slope was visually estimated to be on the order of 0.5% to 1% (Figure 11 to Figure 12). The riparian buffer is well established with ferns and other vegetation (Figure 13).

The channel bed of the reference reach consists of fine gravels to cobbles with few locations with fines and sand. Sandy depositional areas were observed at the channel fringe in locations where eddies are likely to form during high flows due to obstructions from trees and large woody material. The coarse bed material created a pool-riffle morphology, however in the absence of large wood or other channel obstructions the pools were shallow with faster flow velocities that did not allow sand and fines to deposit.

Figure 11. Large woody material and small pool

Figure 12. Reference reach looking downstream

Figure 13. Example of typical bank vegetation

Data Collection:

Data was collected by staff engineers from David Evans and Associates, Inc. on November 29th, 2021. The field crew included the lead author for the PHD at this site, both junior and senior engineers with experience in Fish Passage projects, and a Geomorphologist.

The upstream end of the site was visited first. Observations were recorded, including two pebble counts and four bankfull width measurements. The natural conditions of the upstream reflected an appropriate reference reach. Next, the downstream side of the culvert was visited. A single pebble count and two bankfull width measurements were recorded downstream.

Observations:

The site visit occurred during winter baseflow conditions. The culvert inlet was clear of debris and blockage, with sand and pebble deposits directly upstream of the culvert. The culvert outlet flows into a large scour pool immediately downstream of the outlet, approximately 30 feet by 25 feet. The culvert was installed at a mild slope and does not appear to significantly limit water or sediment capacity.

The channel is in a confined valley with steep hillslopes on either side. In the vicinity of the culvert there is a narrow alluvial flat that makes up the overbanks of the channel. The channel is not incised, and the overbanks are readily accessible during flood flows. The channel exhibits some meandering but generally has low sinuosity. The smallest meander radius is downstream of the culvert where the channel is laterally confined by steep bank and hillslope of consolidated clay material. The bank in this clay material is near vertical and it extends up to approximately 5 feet above the water level. There are pools approximately 2 feet deep adjacent to the bank where the gravel bed material has washed through indicating that scour is being directed downwards to the bed by the clay banks that are resistant to erosion.

The channel bed is dominated by coarse material ranging from fine gravels to cobbles. These materials create a low-amplitude pool-riffle sequence where the flow over the riffles is less than 6 inches deep and the flow through the pools is less than 12 inches deep. Because of the shallow pools the bed material is relatively consistent throughout the reach and there is not much channel complexity. There is no evidence of recent erosion in the form of downcutting or lateral migration indicating that the channel is vertically and laterally stable with this simple geometry. There are locations that are influenced by single pieces of large wood or trees (Figure 11 to Figure 13) that have locally created greater channel complexity in the form of deeper pools, sand deposition, and bank undercutting. There was one large wood complex consisting of multiple pieces of wood material downstream of the culvert outlet (Figure 14). Increasing the amount of wood material in the channel will improve habitat but is not necessary for channel stability.

Figure 14. Large woody material downstream of culvert

Pebble Counts:

Three Wolman Pebble Counts (PC) were conducted at this site. See Figure 15 for PC locations.

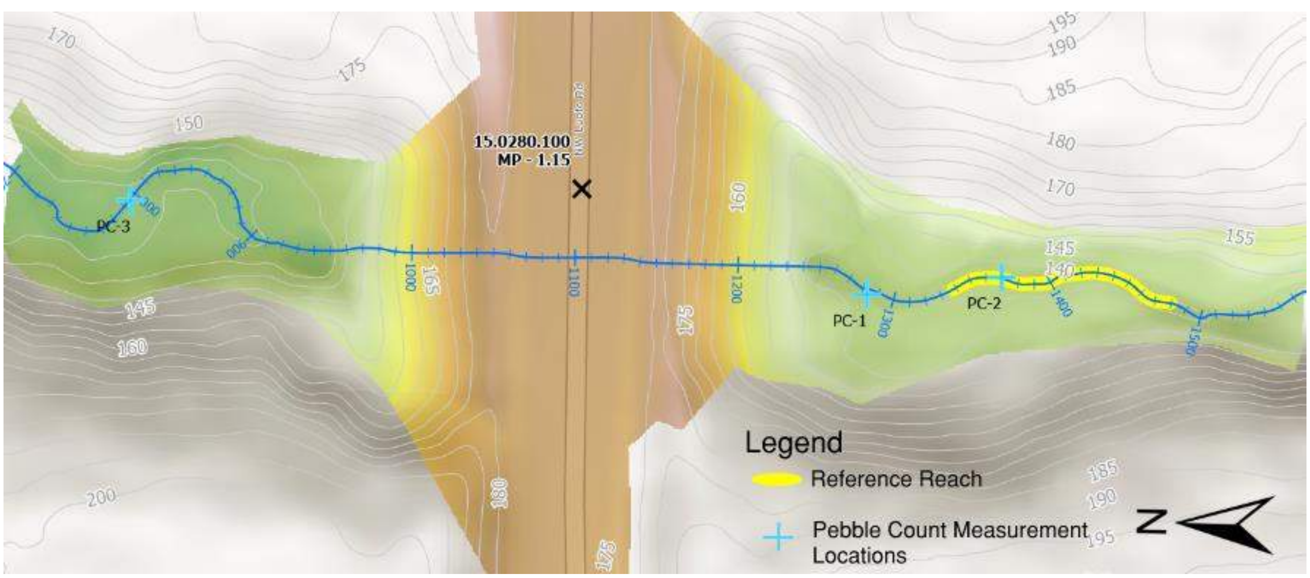


Figure 15. Pebble Count Locations

PC-1 was conducted along a length of stream approximately 50 feet upstream of the existing culvert inlet. The sediment here consisted of coarse sands, gravels, and small cobbles 90 millimeters or less. See Figure 16 and 17.

Figure 16. PC-1 Sediment w/ Gravelometer

Figure 17. PC-1 Sediment in Hand

PC-2 was conducted along a length of stream approximately 140 feet upstream of the existing culvert inlet. The sediment here consisted of coarse sands, gravels, and small cobbles 90 millimeters or less. The pebble count location within the reference reach was taken over a distance of about 50 feet that exhibited faster flow and few fines, therefore this pebble count represents the upper size limit of coarse material that could be mobilized by the stream without the influence of wood material or other potential grade controls. In slackwater areas such as pools or eddies this material will become overtopped with sand as was observed locally within the reach. See Figure 18 and 19.

Figure 18. PC-2 Sediment w/ Gravelometer

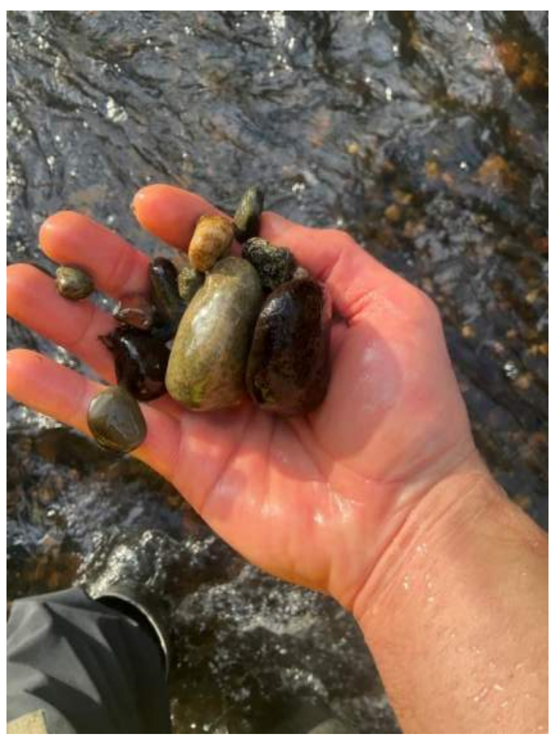


Figure 19. PC-2 Sediment in Hand

PC-3 was conducted along a length of stream approximately 125 feet downstream of the culvert outlet outside of the reference reach. The PC was fairly consistent with PCs conducted upstream of the culvert. See Figure 20 and 21.

Figure 20. PC-3 Sediment w/ Gravelometer

Figure 21. PC-3 Sediment in Hand

Photos:
Any relevant photographs placed here with descriptions.

Samples:	
Work within the wetted perimeter may only occur during the time periods authorized in the APP ID 21036 entitled "Allowable Freshwater Work Times May 2018". Work outside of the wetted perimeter may occur year-round. APPS website: https://www.govonlinesaas.com/WA/WDFW/Public/Client/WA_WDFW/Shared/Pages/Main/Login.aspx	
Were any sample(s) collected from below the OHWM?	*No ☐ If no, then stop here.* *Yes ☐ If yes, then fill out the proceeding section for each sample.*

Sample #:	Work Start:	Work End:	Latitude:	Longitude:
PC-1 and PC-2	Nov. 29, 2021 12:00pm	Nov. 29, 2021 1:20pm	47.70458	-122.66195

Summary/description of location:
Three Wolman Pebble Counts (PC) were taken at this location. Two PCs were conducted upstream of the culvert outlet, one approximately 50 feet and one 140 feet upstream of the culvert inlet. Another PC was conducted approximately 125 feet downstream of the culvert outlet.
Description of work below the OHWL:
Work within the OHW included Wolman Pebble Counts which consists of walking along the streambed to collect 100 random samples of sediment. These samples are then measured in-situ to determine the gradation of the existing streambed sediment. After being measured, the samples are returned to the stream.
Description of problems encountered:
No problems were encountered.

Concurrence Meeting

Concurrence Meeting	Date: December 17, 2022	Time of Arrival: AM
Prepared By: Mike Rice	Weather: Cloudy, scattered showers	Time of Departure:

Attendance List:

Name	Organization	Role
Mike Rice	David Evans and Associates, Inc.	Senior Engineer
Micco Emeson	David Evans and Associates, Inc.	Junior Engineer
David Collins	WDFW	Biologist
Cade Roler	WSDOT	Engineer
Amber Martens	WDFW	Biologist
Alison O' Sullivan	Suquamish Tribe	Tribal representative

Bankfull Width:

BFW-6 was measured 130 feet downstream of the SR 308 culvert outside of the reference reach. The width was measured downstream of a channel bend restricted by natural clay deposits (Figure 7). The measured BFW was 13 feet.

Figure 22. Additional BFW measurement location

Reference Reach:
There was concurrence on the selection of reference reach among all parties.

Observations:

Key observations are summarized below:

- Co-managers measured bankfull widths of 13 feet and recommended this as the design width.
- Large boulders were present along the creek, with diameters ranging between 2 feet and 4 feet.
- Baffles were present within the existing culvert, although it appeared some the baffles may be missing.
- A storm sewer drain pipe was observed with pulsing flow located to the west of the culvert.

Photos:

Figure 23. Baffles inside of culvert

Fish Passage Project Site Visit - Determining Project Complexity

PROJECT NAME:	Big Scandia Creek
WDFW SITE ID:	15.0280 1.00
STATE ROUTE/MILEPOST:	SR 308 MP 1.15
SITE VISIT DATE:	December 17, 2021
ATTENDEES:	Mike Rice, Micco Emeson, David Collins, Cade Roler, Amber Martens, Alison O'Sullivan
ANTICIPATED LEVEL OF PROJECT COMPLEXITY - Low/Medium/High (*additional considerations or red flags may trigger the need for new discussions*):	Medium
IN WATER WORK WINDOW	

The following elements of projects should be discussed before the production of a Preliminary Hydraulic Design by members of WSDOT and WDFW to identify the level of complexity for each site, and corresponding communication and review. While certain elements may be categorized as indicators of a low/medium/high complexity project, these are only suggestions, and newly acquired information may change the level of complexity during a project. The ultimate documentation category for a given site is up to both WSDOT and WDFW, considering both site characteristics and synergistic effects.

Discuss the following elements as they apply to the project. Rank each element as low, medium, or high in complexity. If there are items that need follow-up, mark those and provide a brief description in the column labeled, “Is follow up needed on this item?” The assigned level of complexity determines the appropriate agreed upon review from WDFW (see review parameters here (*final full doc goes here*)). Ultimately, WSDOT needs to acquire an HPA from WDFW for fish passage projects and the agreed upon communication and review of project elements will contribute to efficiencies in the permitting process.

Fish Passage Project Site Visit - Determining Project Complexity

Project Elements (anticipated)	Low Complexity	Medium Complexity	High Complexity	Is follow up needed on this item?
Stream grading	✓			
Risk of degradation/aggradation	✓			
Channel realignment	✓			
Expected stream movement		✓		
Gradient	✓			
Potential for backwater impacts	✓			
Meeting requirements for freeboard	✓			
Stream size, and Bankfull Width	✓			
Slope ratio	✓			Confirm through survey
Sediment supply	✓			
Meeting stream simulation	✓			
Channel confinement		✓		
Geotech or seismic considerations		✓		Clay layer observed and lots of groundwater
Tidal influence	✓			
Alluvial fan	✓			
Fill depth above barrier		✓		
Presence of other nearby barriers	✓			
Presence of nearby infrastructure		✓		Intersection nearby - MOT and roadway challenge
Need for bank protection		✓		Lateral migration risk - may need protection
Floodplain utilization ratio		✓		

Other:				
Utilities Challenges				
Sump pump discharge on upstream leftbank				
ROW fencing and remove trash from stream				

Appendix C: Streambed Material Sizing Calculations

Summary - Stream Simulation Bed Material Design

Project:	**15.0280 1.00 - Big Scandia to Liberty Bay**
By:	**David Evans and Associates; Atalia Raskin / Tonmoy Sarker**

Design Gradation

Location:	Proposed Channel			
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.3**	**0.2**	**0.1**	**0.0**
in	**4.0**	**2.3**	**1.2**	**0.1**
mm	**102**	**58**	**31.5**	**3.2**

Existing Gradation

Location:				
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.00**	**0.00**	**0.00**	**0.00**
in				
mm	**0**	**0**	**0.0**	**0.0**

Existing Gradation

Location:				
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.00**	**0.00**	**0.00**	**0.00**
in				
mm	**0**	**0**	**0.0**	**0.0**

Existing Gradation

Location:	Existing Average			
	D_{100}	**D_{84}**	**D_{50}**	**D_{16}**
ft	**0.4**	**0.2**	**0.1**	**0.0**
in	**4.70**	**1.80**	**0.90**	**0.40**
mm	**119**	**46**	**22.9**	**10.2**

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

Rock Size		**Streambed**	**Streambed Cobbles**					**Streambed Boulders**			**D_{size}**
[in]	**[mm]**	**Sediment**	**4"**	**6"**	**8"**	**10"**	**12"**	**12"-18"**	**18"-28"**	**28"-36"**	
36.0	**914**									**100**	**100.0**
32.0	**813**									50	**100.0**
28.0	**711**								**100**		**100.0**
23.0	**584**								50		**100.0**
18.0	**457**							**100**			**100.0**
15.0	**381**							50			**100.0**
12.0	**305**						**100**				**100.0**
10.0	**254**					**100**	**80**				**100.0**
8.0	**203**				**100**	**80**	68				**100.0**
6.0	**152**			**100**	**80**	68	57				**100.0**
5.0	**127**			**80**	68	57	**45**				**100.0**
4.0	**102**		**100**	71	57	**45**	40				**100.0**
3.0	**76.2**		**80**	63	**45**	38	35				**95.0**
2.5	**63.5**	**100**	63	54	37	32	30				**90.8**
2.0	**50.8**	**85**	47	**45**	29	25	25				**75.4**
1.5	**38.1**	68	**30**	32	21	18	20				**58.1**
1.0	**25.4**	**50**	20	18	13	12	15				**42.5**
0.50	**12.7**	**45**	**5**	**5**	**5**	**5**	**10**				**35.0**
0.19	**4.75**	28									**20.6**
0.02	**0.425**	**10**									**7.5**
0.003	**0.0750**	**5**									**3.8**
% per category		**75**	**25**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	*--> 100%*
% Cobble & Sediment		**75.0**	**25.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	*100.0%*

Streambed Mobility/Stability Analysis

Modified Shields Approach

References:

United States Forest Service (USFS)

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

Appendix E - Methods for Streambed Mobility/Stability Analysis

Range of Suitability:

$D_{84\ ranging}$ between 0.40 in and 10 in

Uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

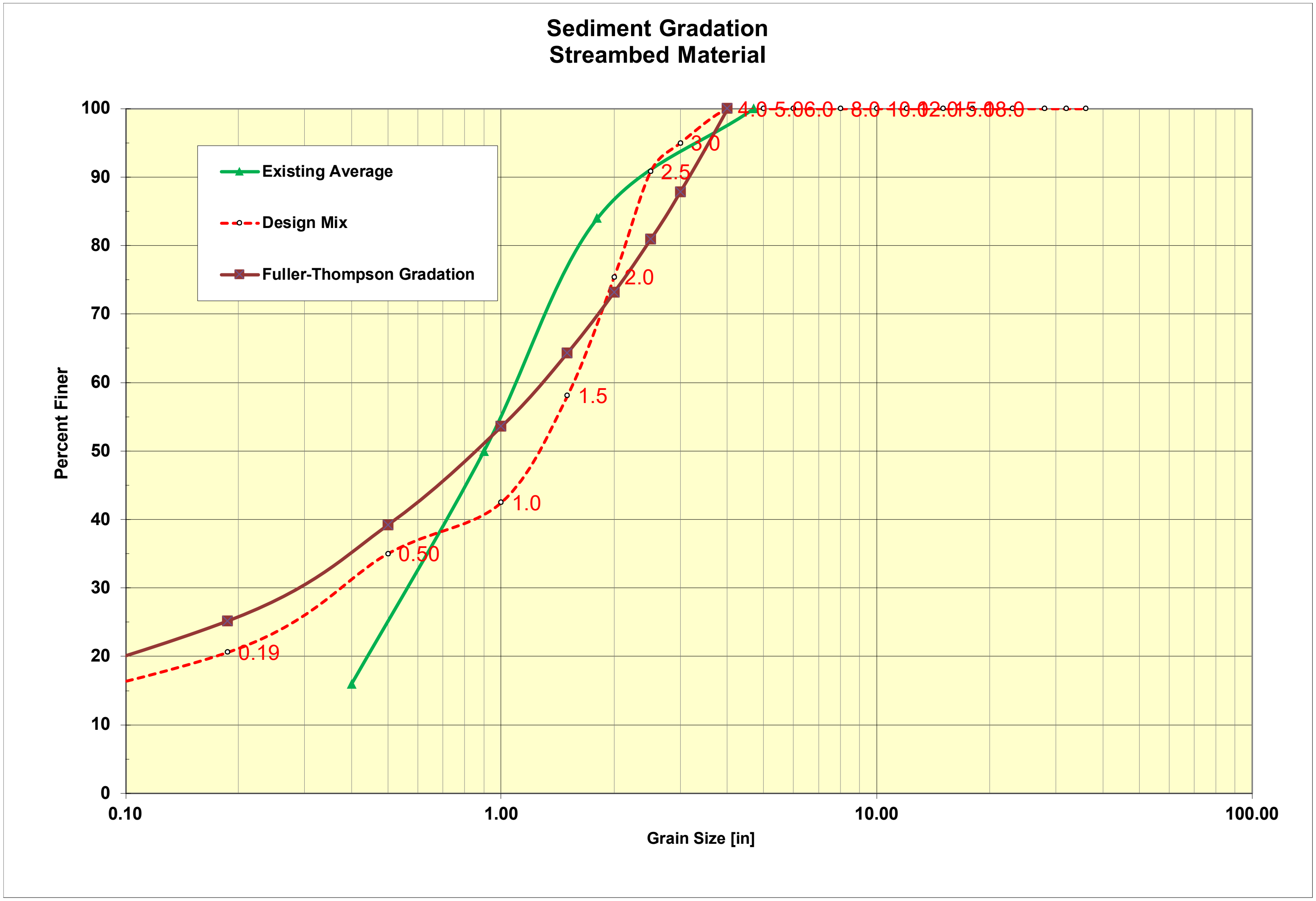
γ_s =	165	specific weight of sediment particle (lb/ft^3)
γ =	62.4	specific weight of water (lb/ft^3)
τ_{D50} =	0.047	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

τ_{ci} = the critical shear stress at which the sediment particle of interest begins to move (lb/ft^2 or N/m^2)

Average Modeled Shear Stress (lb/ft^2)

Rock Size [in]	D_{size}	τ_{ci}	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
			1.10	2.60	3.10	3.60	3.90	4.40
36.0	100.0	1.37	No Motion	Motion	Motion	Motion	Motion	Motion
32.0	100.0	1.32	No Motion	Motion	Motion	Motion	Motion	Motion
28.0	100.0	1.27	No Motion	Motion	Motion	Motion	Motion	Motion
23.0	100.0	1.20	No Motion	Motion	Motion	Motion	Motion	Motion
18.0	100.0	1.11	No Motion	Motion	Motion	Motion	Motion	Motion
15.0	100.0	1.05	Motion	Motion	Motion	Motion	Motion	Motion
12.0	100.0	0.98	Motion	Motion	Motion	Motion	Motion	Motion
10.0	100.0	0.93	Motion	Motion	Motion	Motion	Motion	Motion
8.0	100.0	0.87	Motion	Motion	Motion	Motion	Motion	Motion
6.0	100.0	0.80	Motion	Motion	Motion	Motion	Motion	Motion
5.0	100.0	0.76	Motion	Motion	Motion	Motion	Motion	Motion
4.0	100.0	0.71	Motion	Motion	Motion	Motion	Motion	Motion
3.0	95.0	0.65	Motion	Motion	Motion	Motion	Motion	Motion
2.5	90.8	0.61	Motion	Motion	Motion	Motion	Motion	Motion
2.0	75.4	0.58	Motion	Motion	Motion	Motion	Motion	Motion
1.5	58.1	0.53	Motion	Motion	Motion	Motion	Motion	Motion
1.0	42.5	0.47	Motion	Motion	Motion	Motion	Motion	Motion
0.5	35.0	0.38	Motion	Motion	Motion	Motion	Motion	Motion
0.2	20.6	0.28	Motion	Motion	Motion	Motion	Motion	Motion
0.0	7.5	0.14	Motion	Motion	Motion	Motion	Motion	Motion
0.0	3.8	0.08	Motion	Motion	Motion	Motion	Motion	Motion

D_{50} =	**1.24**	in	D_{95} =	**3.00**	in
	0.10	ft		0.25	ft
	31.5	mm		76.2	mm



Fuller-Thompson Gradation

Dmax = 4.00

Rock Size [in]	D_{size}
36.0	268.8
32.0	254.9
28.0	240.0
23.0	219.7
18.0	196.8
15.0	181.3
12.0	163.9
10.0	151.0
8.0	136.6
6.0	120.0
5.0	110.6
4.0	100.0
3.0	87.9
2.5	80.9
2.0	73.2
1.5	64.3
1.0	53.6
0.5	39.2
0.2	25.2
0.02	8.5
0.003	3.9

Summary - Meander Bar Head

Project:	**15.0280 1.00 - Big Scandia to Liberty Bay**
By:	**David Evans and Associates; Atalia Raskin / Tonmoy Sarker**

Design Gradation				
Location: Proposed Channel				
	D_{100}	D_{84}	D_{50}	D_{16}
ft	1.5	1.4	1.1	0.1
in	18.0	16.6	13.7	1.1
mm	457	422	348.3	27.8

Existing Gradation				
Location:				
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.00	0.00	0.00	0.00
in				
mm	0	0	0.0	0.0

Existing Gradation				
Location:				
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.00	0.00	0.00	0.00
in				
mm	0	0	0.0	0.0

Existing Gradation				
Location: Existing Average				
	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.4	0.2	0.1	0.0
in	4.70	1.80	0.90	0.40
mm	119	46	22.9	10.2

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

Rock Size		Streambed	Streambed Cobbles					Streambed Boulders			D_{size}
[in]	[mm]	Sediment	4"	6"	8"	10"	12"	12"-18"	18"-28"	28"-36"	
36.0	914									100	100.0
32.0	813									50	100.0
28.0	711								100		100.0
23.0	584								50		100.0
18.0	457							100			100.0
15.0	381							50			65.0
12.0	305						100				30.0
10.0	254					100	80				30.0
8.0	203				100	80	68				30.0
6.0	152			100	80	68	57				30.0
5.0	127			80	68	57	45				30.0
4.0	102		100	71	57	45	39				30.0
3.0	76.2		80	63	45	38	34				30.0
2.5	63.5	100	63	54	37	32	28				30.0
2.0	50.8	85	47	45	29	25	22				25.5
1.5	38.1	68	30	32	21	18	16				20.3
1.0	25.4	50	20	18	13	12	11				15.0
0.50	12.7	45	5	5	5	5	5				13.5
0.19	4.75	28									8.3
0.02	0.425	10									3.0
0.003	0.0750	5									1.5
% per category		30	0	0	0	0	0	70	0	0	*--> 100%*
% Cobble & Sediment		100.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	*200.0%*

Meander Bar Head Mobility/Stability Analysis

Modified Shields Approach

References:

United States Forest Service (USFS)

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

Appendix E - Methods for Streambed Mobility/Stability Analysis

Range of Suitability:

$D_{84\ ranging}$ between 0.40 in and 10 in

Uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

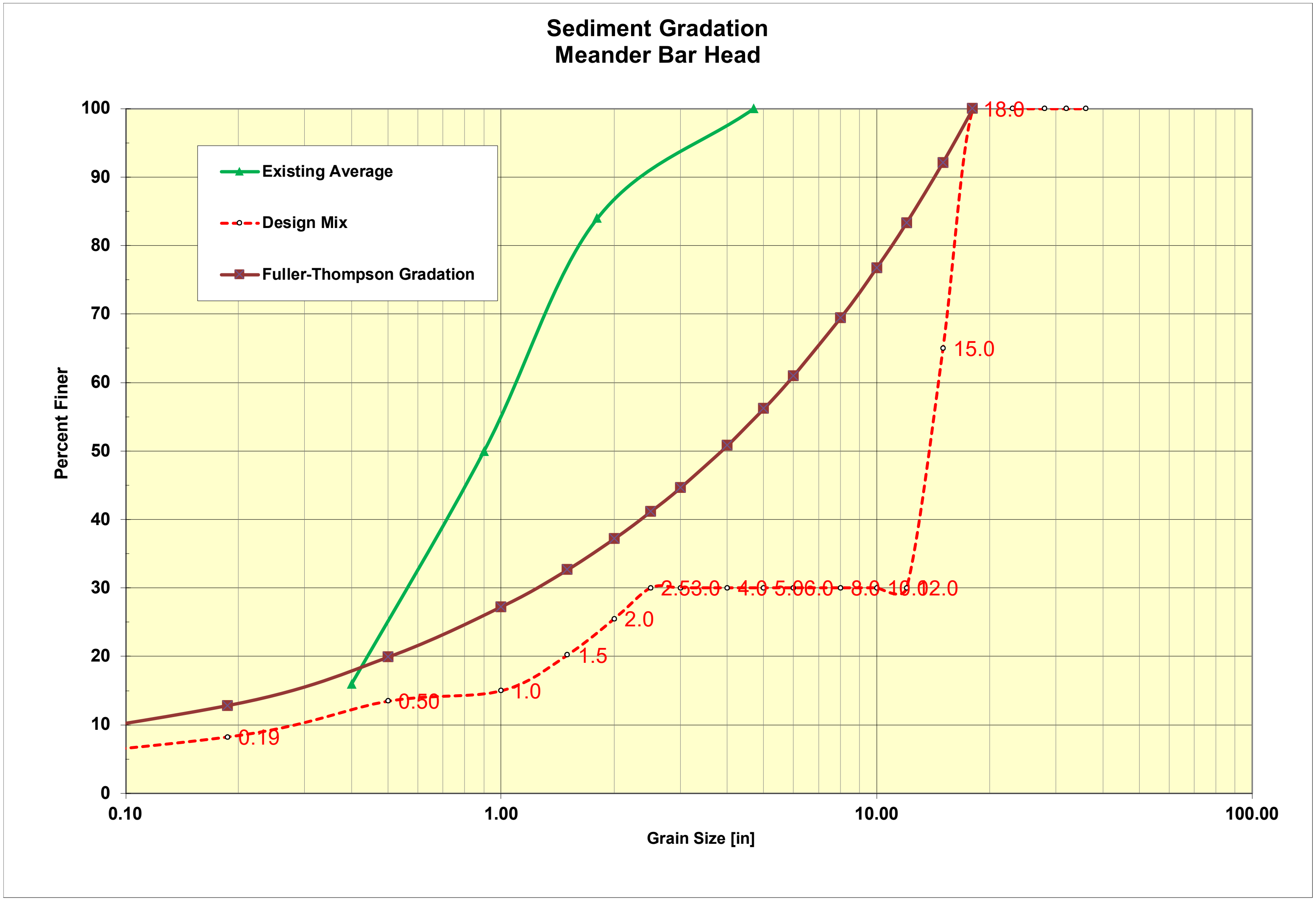
γ_s =	165	specific weight of sediment particle (lb/ft^3)
γ =	62.4	specific weight of water (lb/ft^3)
τ_{D50} =	0.054	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

τ_{ci} = the critical shear stress at which the sediment particle of interest begins to move (lb/ft^2 or N/m^2)

Average Modeled Shear Stress (lb/ft^2)

Rock Size [in]	D_{size}	τ_{ci}	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
			1.10	2.60	3.10	3.60	3.90	4.40
36.0	100.0	8.46	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
32.0	100.0	8.16	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
28.0	100.0	7.84	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
23.0	100.0	7.39	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
18.0	100.0	6.87	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
15.0	65.0	6.50	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
12.0	30.0	6.08	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
10.0	30.0	5.76	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
8.0	30.0	5.39	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
6.0	30.0	4.94	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
5.0	30.0	4.68	No Motion	No Motion	No Motion	No Motion	No Motion	No Motion
4.0	30.0	4.38	No Motion	No Motion	No Motion	No Motion	No Motion	Motion
3.0	30.0	4.01	No Motion	No Motion	No Motion	No Motion	No Motion	Motion
2.5	30.0	3.80	No Motion	No Motion	No Motion	No Motion	Motion	Motion
2.0	25.5	3.55	No Motion	No Motion	No Motion	Motion	Motion	Motion
1.5	20.3	3.26	No Motion	No Motion	No Motion	Motion	Motion	Motion
1.0	15.0	2.89	No Motion	No Motion	Motion	Motion	Motion	Motion
0.5	13.5	2.34	No Motion	Motion	Motion	Motion	Motion	Motion
0.2	8.3	1.75	No Motion	Motion	Motion	Motion	Motion	Motion
0.0	3.0	0.85	Motion	Motion	Motion	Motion	Motion	Motion
0.0	1.5	0.50	Motion	Motion	Motion	Motion	Motion	Motion

D_{50} =	**13.71**	in	D_{95} =	**17.57**	in
	1.14	ft		1.46	ft
	348.3	mm		446.3	mm



Fuller-Thompson Gradation

Dmax = 18.00

Rock Size [in]	D_{size}
36.0	136.6
32.0	129.6
28.0	122.0
23.0	111.7
18.0	100.0
15.0	92.1
12.0	83.3
10.0	76.8
8.0	69.4
6.0	61.0
5.0	56.2
4.0	50.8
3.0	44.7
2.5	41.1
2.0	37.2
1.5	32.7
1.0	27.2
0.5	19.9
0.2	12.8
0.02	4.3
0.003	2.0

Summary - Meander Bar Tail

Project:	15.0280 1.00 - Big Scandia to Liberty Bay
By:	David Evans and Associates; Atalia Raskin / Tonmoy Sarker

Design Gradation

Location: Proposed Channel

	D_{100}	D_{84}	D_{50}	D_{16}
ft	1.5	1.1	0.4	0.1
in	18.0	13.2	4.4	0.8
mm	457	335	113.0	19.7

Existing Gradation

Location:

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.00	0.00	0.00	0.00
in				
mm	0	0	0.0	0.0

Existing Gradation

Location:

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.00	0.00	0.00	0.00
in				
mm	0	0	0.0	0.0

Existing Gradation

Location: Existing Average

	D_{100}	D_{84}	D_{50}	D_{16}
ft	0.4	0.2	0.1	0.0
in	4.70	1.80	0.90	0.40
mm	119	46	22.9	10.2

Determining Aggregate Proportions

Per WSDOT Standard Specifications 9-03.11

Rock Size		Streambed	Streambed Cobbles					Streambed Boulders			D_{size}
[in]	[mm]	Sediment	4"	6"	8"	10"	12"	12"-18"	18"-28"	28"-36"	
36.0	914									100	100.0
32.0	813									50	100.0
28.0	711								100		100.0
23.0	584								50		100.0
18.0	457							100			100.0
15.0	381							50			90.0
12.0	305						100				80.0
10.0	254					100	80				70.0
8.0	203				100	80	68				63.8
6.0	152			100	80	68	55				57.7
5.0	127			80	68	57	43				51.5
4.0	102		100	71	57	45	38				48.8
3.0	76.2		80	63	45	38	32				46.1
2.5	63.5	100	63	54	37	32	27				43.4
2.0	50.8	85	47	45	29	25	21				36.1
1.5	38.1	68	30	32	21	18	16				28.2
1.0	25.4	50	20	18	13	12	10				20.2
0.50	12.7	28	5	5	5	5	5				10.9
0.19	4.75	16									4.7
0.02	0.425	3									0.9
0.003	0.0750	5									1.5
% per category		30	0	0	0	0	50	20	0	0	*--> 100%*
% Cobble & Sediment		37.5	0.0	0.0	0.0	0.0	62.5	100.1	0.0	0.0	*200.1%*

Meander Bar Tail Mobility/Stability Analysis

Modified Shields Approach

References:

United States Forest Service (USFS)

Stream Simulation: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings

Appendix E - Methods for Streambed Mobility/Stability Analysis

Range of Suitability:

$D_{84\ ranging}$ between 0.40 in and 10 in

Uniform bed material (Di < 20-30 times D50)

Slopes less than 5%

Sand/gravel streams with high relative submergence

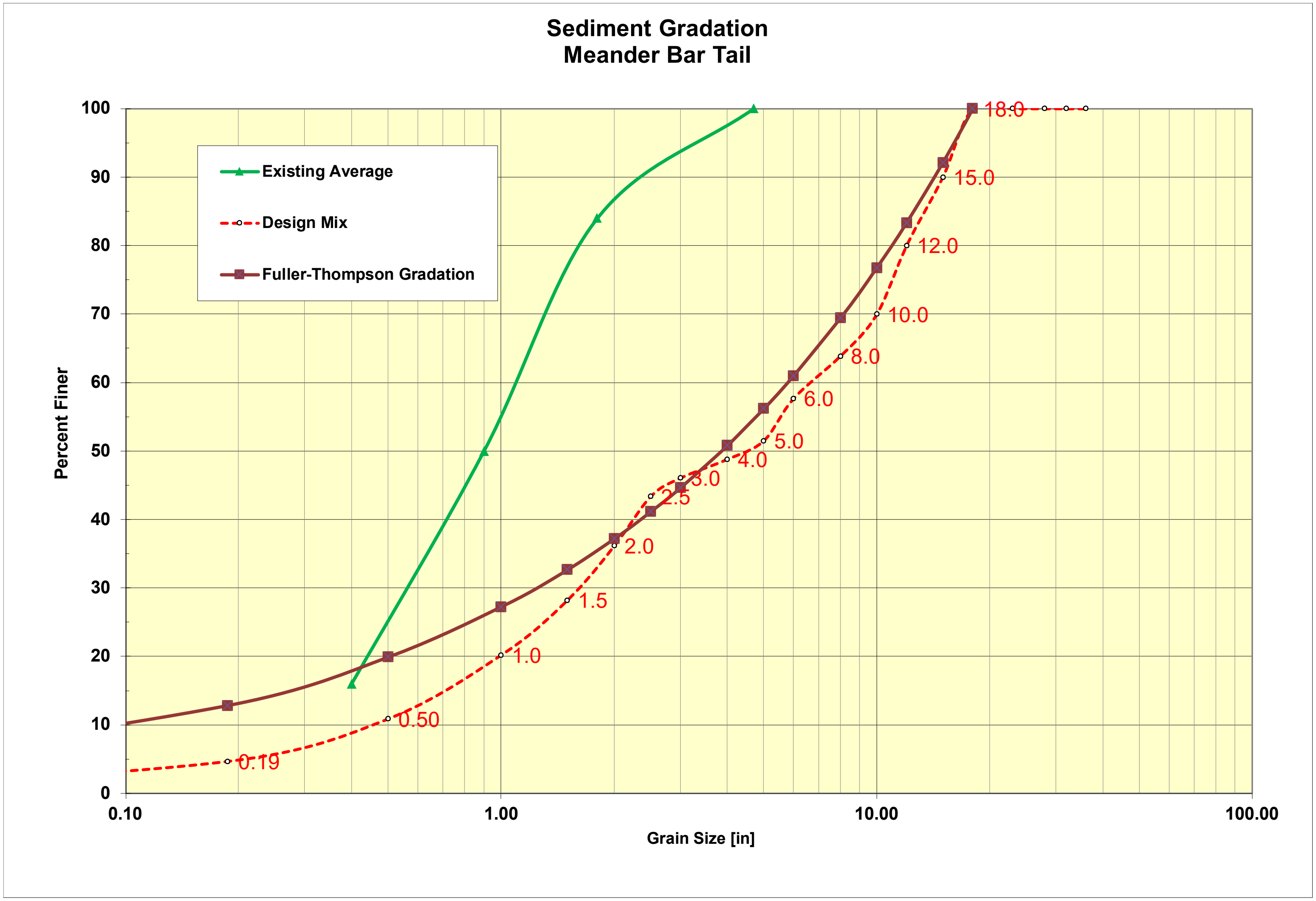
γ_s =	165	specific weight of sediment particle (lb/ft^3)
γ =	62.4	specific weight of water (lb/ft^3)
τ_{D50} =	0.052	dimensionless Shields parameter for D50, use table E.1 of USFS manual or assume 0.045 for poorly sorted channel bed

τ_{ci} = the critical shear stress at which the sediment particle of interest begins to move (lb/ft^2 or N/m^2)

Average Modeled Shear Stress (lb/ft^2)

Rock Size [in]	D_{size}	τ_{ci}	2-Year	10-Year	25-Year	50-Year	100-Year	500-Year
			1.10	2.60	3.10	3.60	3.90	4.40
36.0	100.0	3.70	No Motion	No Motion	No Motion	No Motion	Motion	Motion
32.0	100.0	3.57	No Motion	No Motion	No Motion	Motion	Motion	Motion
28.0	100.0	3.43	No Motion	No Motion	No Motion	Motion	Motion	Motion
23.0	100.0	3.24	No Motion	No Motion	No Motion	Motion	Motion	Motion
18.0	100.0	3.01	No Motion	No Motion	Motion	Motion	Motion	Motion
15.0	90.0	2.85	No Motion	No Motion	Motion	Motion	Motion	Motion
12.0	80.0	2.66	No Motion	No Motion	Motion	Motion	Motion	Motion
10.0	70.0	2.52	No Motion	Motion	Motion	Motion	Motion	Motion
8.0	63.8	2.36	No Motion	Motion	Motion	Motion	Motion	Motion
6.0	57.7	2.16	No Motion	Motion	Motion	Motion	Motion	Motion
5.0	51.5	2.05	No Motion	Motion	Motion	Motion	Motion	Motion
4.0	48.8	1.92	No Motion	Motion	Motion	Motion	Motion	Motion
3.0	46.1	1.76	No Motion	Motion	Motion	Motion	Motion	Motion
2.5	43.4	1.66	No Motion	Motion	Motion	Motion	Motion	Motion
2.0	36.1	1.56	No Motion	Motion	Motion	Motion	Motion	Motion
1.5	28.2	1.43	No Motion	Motion	Motion	Motion	Motion	Motion
1.0	20.2	1.26	No Motion	Motion	Motion	Motion	Motion	Motion
0.5	10.9	1.03	Motion	Motion	Motion	Motion	Motion	Motion
0.2	4.7	0.76	Motion	Motion	Motion	Motion	Motion	Motion
0.0	0.9	0.37	Motion	Motion	Motion	Motion	Motion	Motion
0.0	1.5	0.22	Motion	Motion	Motion	Motion	Motion	Motion

D_{50} =	**4.45**	in	D_{95} =	**16.50**	in
	0.37	ft		1.38	ft
	113.0	mm		419.1	mm

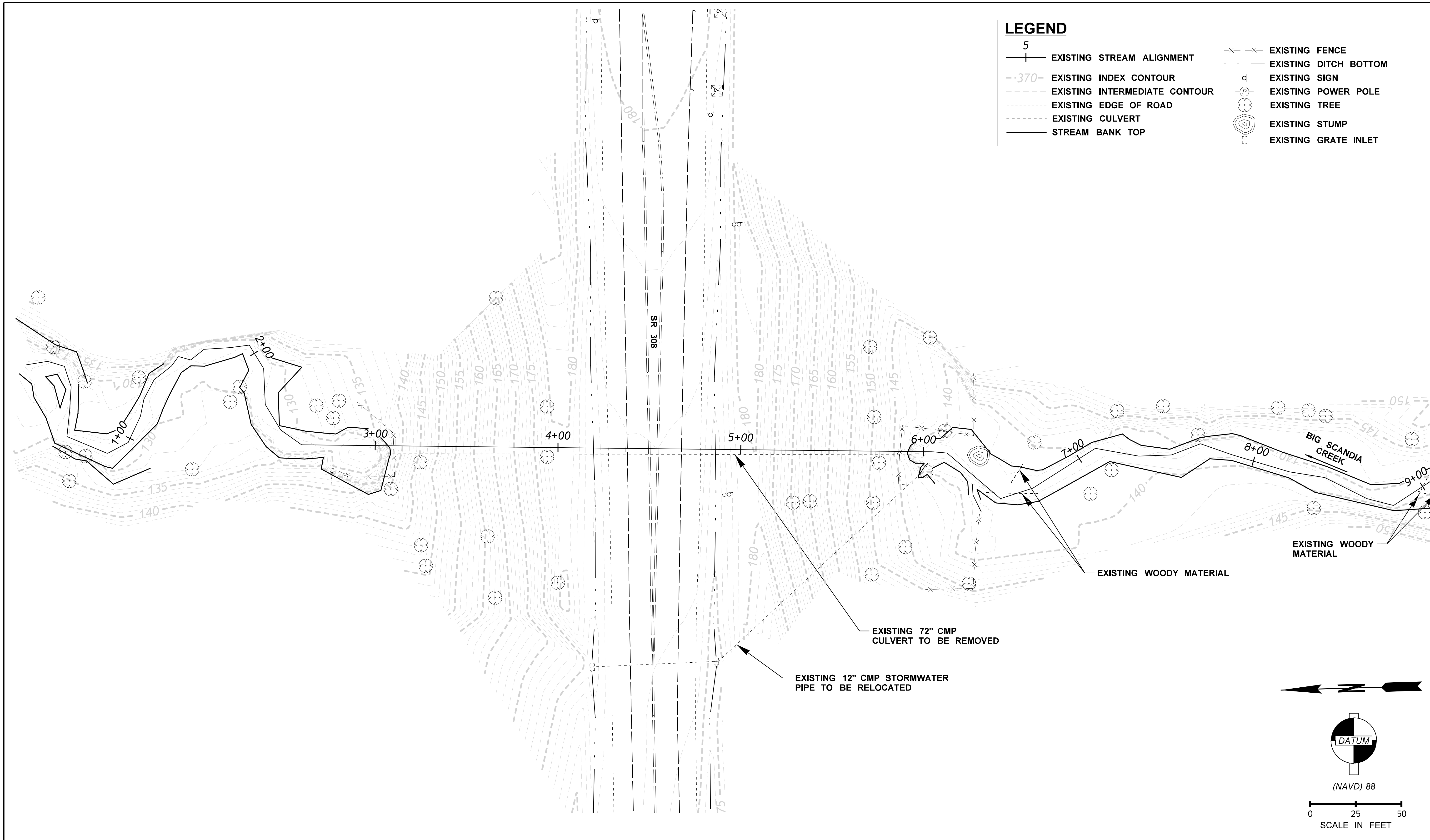


Fuller-Thompson Gradation

Dmax = 18.00

Rock Size [in]	D_{size}
36.0	136.6
32.0	129.6
28.0	122.0
23.0	111.7
18.0	100.0
15.0	92.1
12.0	83.3
10.0	76.8
8.0	69.4
6.0	61.0
5.0	56.2
4.0	50.8
3.0	44.7
2.5	41.1
2.0	37.2
1.5	32.7
1.0	27.2
0.5	19.9
0.2	12.8
0.02	4.3
0.003	2.0

Appendix D: Stream Plan Sheets, Profile, Details



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PLOTTED BY	Rhw
DESIGNED BY	A. RASKIN
ENTERED BY	R. WILCOX
CHECKED BY	-
PROJ. ENGR.	-
REGIONAL ADM.	-

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
	WASH	
JOB NUMBER		
CONTRACT NO.		LOCATION NO.

PRELIMINARY

NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

DAVID EVANS AND ASSOCIATES INC.

SR 308 MP 01.15

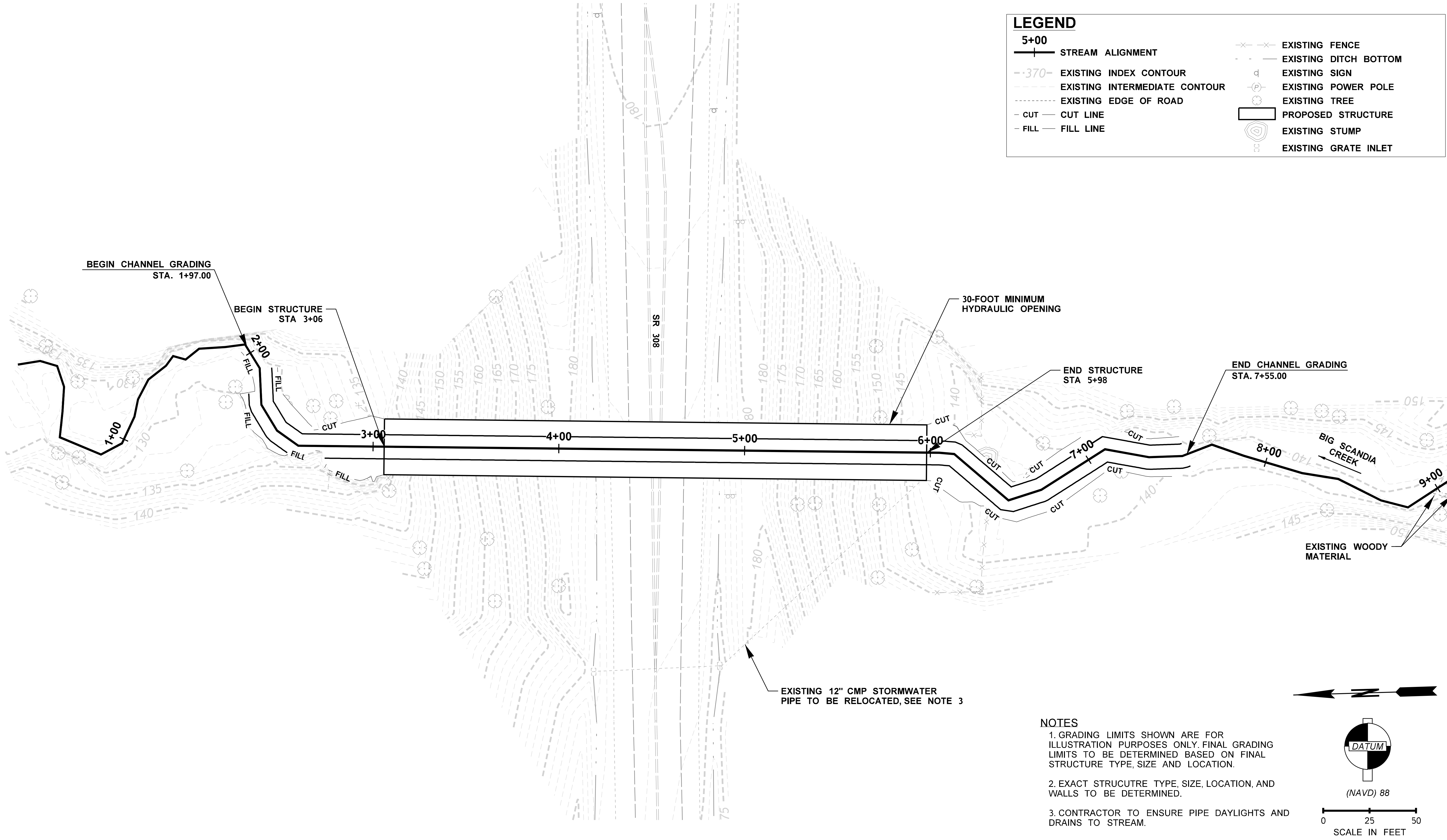
BIG SCANDIA CREEK

FISH BARRIER REMOVAL

STREAM PLAN

PLAN REF NO CE1

SHEET OF SHEETS



LEGEND

5+00	STREAM ALIGNMENT		EXISTING FENCE
			EXISTING DITCH BOTTOM
370	EXISTING INDEX CONTOUR		EXISTING SIGN
	EXISTING INTERMEDIATE CONTOUR	P	EXISTING POWER POLE
	EXISTING EDGE OF ROAD		EXISTING TREE
CUT	CUT LINE		PROPOSED STRUCTURE
FILL	FILL LINE		EXISTING STUMP
			EXISTING GRATE INLET

NOTES

1. GRADING LIMITS SHOWN ARE FOR ILLUSTRATION PURPOSES ONLY. FINAL GRADING LIMITS TO BE DETERMINED BASED ON FINAL STRUCTURE TYPE, SIZE AND LOCATION.

2. EXACT STRUCUTRE TYPE, SIZE, LOCATION, AND WALLS TO BE DETERMINED.

3. CONTRACTOR TO ENSURE PIPE DAYLIGHTS AND DRAINS TO STREAM.

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ENTERED BY	R. WILCOX
CHECKED BY	-
PROJ. ENGR.	-
REGIONAL ADM.	-

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
	WASH	

JOB NUMBER

CONTRACT NO. | LOCATION NO.

PRELIMINARY

NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE

P.E. STAMP BOX DATE

Washington State Department of Transportation

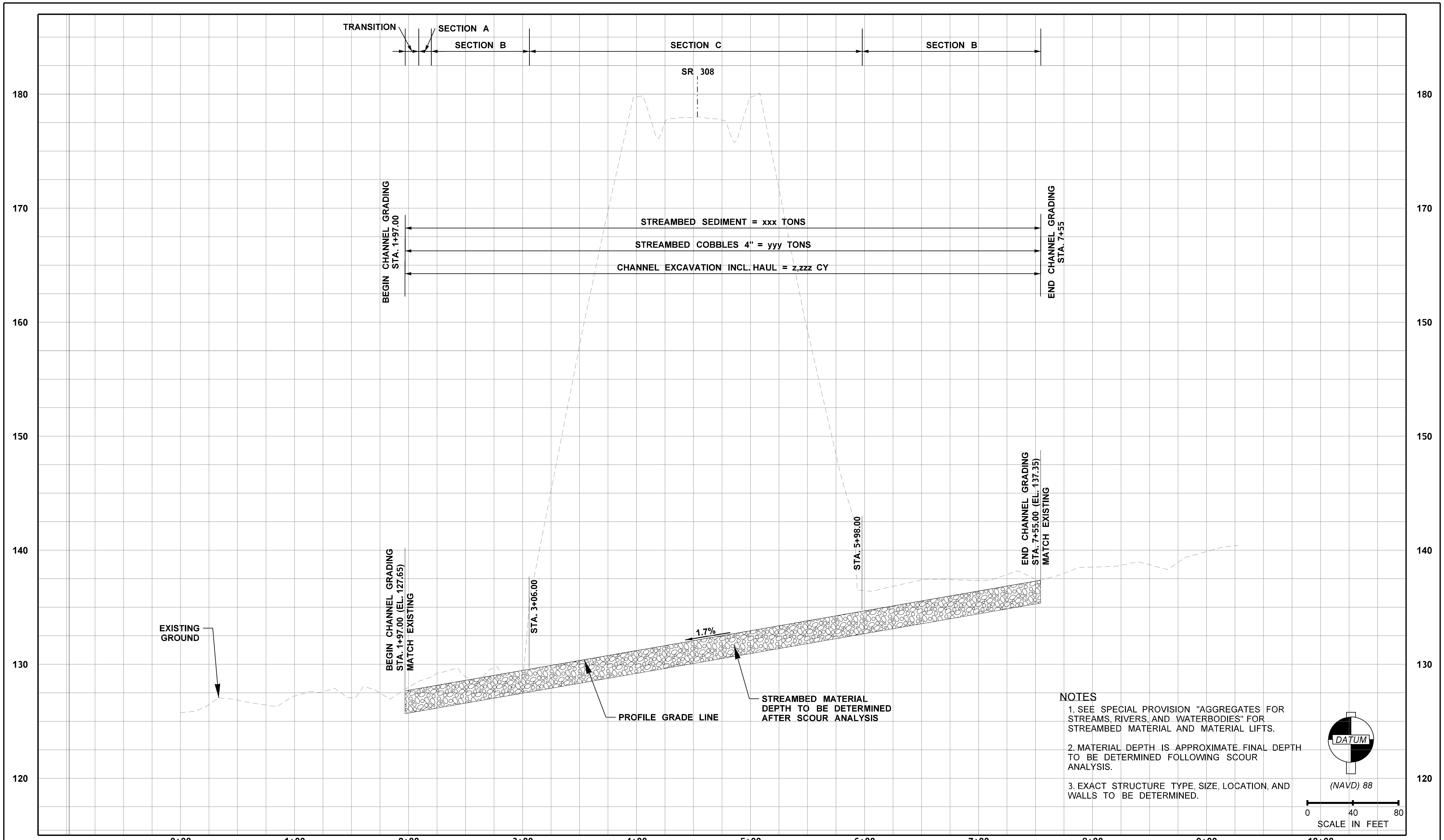
DAVID EVANS AND ASSOCIATES INC.

SR 308 MP 01.15
BIG SCANDIA CREEK
FISH BARRIER REMOVAL

STREAM PLAN

PLAN REF NO
CR1

SHEET
OF
SHEETS



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DESIGNED BY	A. RASKIN
ENTERED BY	R. WILCOX
CHECKED BY	-
PROJ. ENGR.	-
REGIONAL ADM.	-

REVISION | DATE | BY

REGION NO. | STATE WASH | FED.AID PROJ.NO.

JOB NUMBER

CONTRACT NO. | LOCATION NO.

PRELIMINARY

NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE | P.E. STAMP BOX DATE

Washington State Department of Transportation

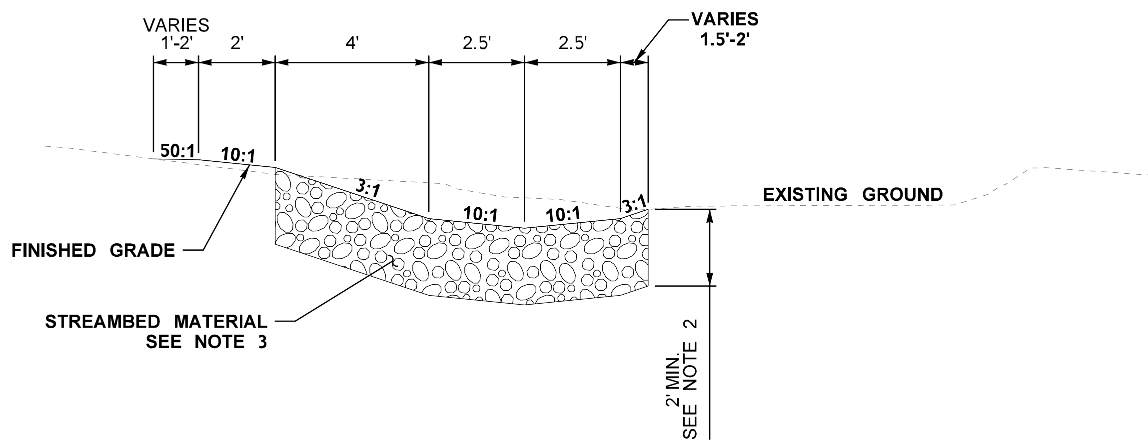
DAVID EVANS AND ASSOCIATES INC.

SR 308 MP 01.15
BIG SCANDIA CREEK
FISH BARRIER REMOVAL

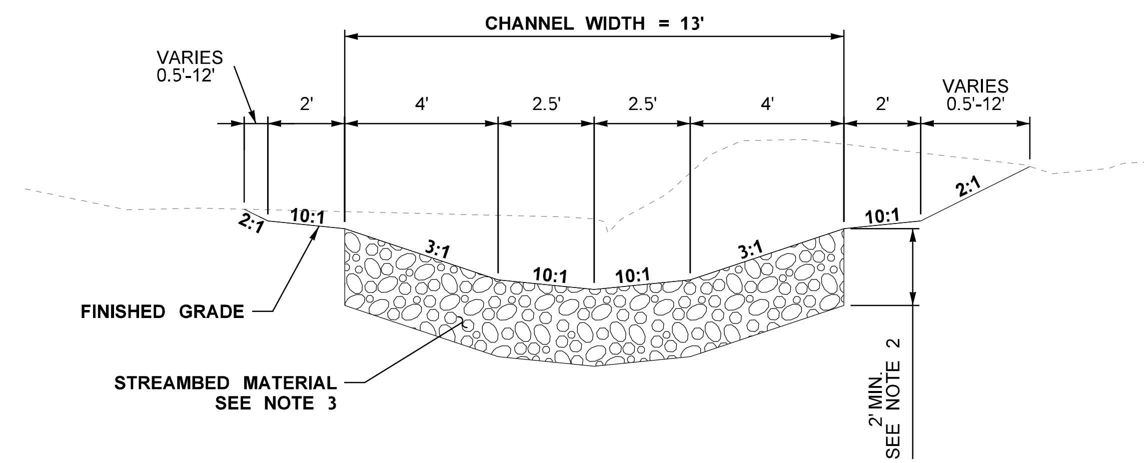
STREAM PROFILE

PLAN REF NO CP1

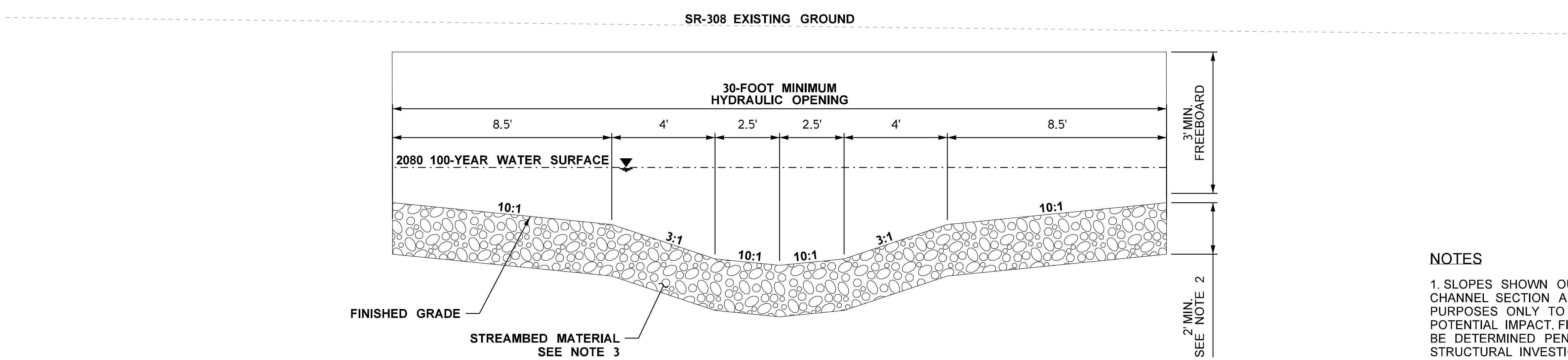
SHEET OF SHEETS



SECTION A
STATION 2+09.00 TO 2+22.00



SECTION B
STATION 2+22.00 TO 3+06.00
STATION 5+98.00 TO 7+55.00



SECTION C
STATION 3+06.00 TO 5+98.00

NOTES

1. SLOPES SHOWN OUTSIDE OF THE MINIMUM CHANNEL SECTION ARE FOR ILLUSTRATIVE PURPOSES ONLY TO DEPICT ESTIMATED AREA OF POTENTIAL IMPACT. FINAL AREAS OF IMPACT TO BE DETERMINED PENDING GEOTECHNICAL AND STRUCTURAL INVESTIGATION, STRUCTURE TYPE, AND STRUCTURE LOCATION.

2. MATERIAL DEPTH IS APPROXIMATE, FINAL DEPTH TO BE DETERMINED AFTER SCOUR ANALYSIS.

3. SEE SPECIAL PROVISION "AGGREGATES FOR STREAMS, RIVERS AND WATERBODIES".

4. FROM STA 1+97.00 TO 2+08.00, EVENLY TAPER SECTION A TO MATCH EXISTING CHANNEL.

5. FROM STA 7+50.00 TO 7+55.00, EVENLY TAPER SECTION B TO MATCH EXISTING CHANNEL.

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ENTERED BY	R. WILCOX
CHECKED BY	-
PROJ. ENGR.	-
REGIONAL ADM.	-

REVISION	DATE	BY

REGION NO.	STATE	FED.AID PROJ.NO.
	WASH	
JOB NUMBER		
CONTRACT NO.		LOCATION NO.

PRELIMINARY
NOT FOR CONSTRUCTION

P.E. STAMP BOX DATE
P.E. STAMP BOX DATE

Washington State Department of Transportation

DAVID EVANS AND ASSOCIATES INC.

SR 308 MP 01.15
BIG SCANDIA CREEK
FISH BARRIER REMOVAL

STREAM DETAILS

PLAN REF NO CD1
SHEET OF SHEETS

Appendix E: Manning's Calculations (Not Used)

Appendix F: Large Woody Material Calculations

WSDOT Large Woody Material for stream restoration metrics calculator

State Route# & MP	*SR 308 MP 1.15*	Key piece volume	*1.310*	*yd3*
Stream name	*Big Scandia Creek, Culvert Design*	Key piece/ft	*0.0335*	*per ft stream*
length of regrade[a]	*558* ft	Total wood vol./ft	*0.3948*	*yd3/ft stream*
Bankfull width	*13* ft	Total LWM[c] pieces/ft stream	*0.1159*	*per ft stream*
Habitat zone[b]	*Western WA*			

Taper coeff.	-0.01554
LF_{rw}	1.5
H_{dbh}	4.5

Log type	*Diameter at midpoint (ft)*	*Length(ft)[d]*	*Volume (yd^3/log)[d]*	*Rootwad?*	*Qualifies as key piece?*	*No. LWM pieces*	*Total wood volume (yd^3)*
A	2.00	30	3.49	yes	yes	7	24.43
B	1.50	24	1.57	yes	yes	12	18.85
C	1.50	15	0.98	yes	no	6	5.89
D	1	10	0.29	no	no	5	1.45
E	0.5	10	0.07	no	no	11	0.80
F			0.00				0.00
G			0.00				0.00
H			0.00				0.00
I			0.00				0.00
J			0.00				0.00
K			0.00				0.00
L			0.00				0.00
M			0.00				0.00
N			0.00				0.00
O			0.00				0.00
P			0.00				0.00

DBH based on mid point diameter (ft)	$D_{root\ collar\ (ft)}$	L/2-Lrw (ft)
2.12	2.19	12
1.58	1.65	9.75
1.51	1.58	5.25
1.08	1.05	3.5
0.58	0.57	4.25
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0
	0.00	0

	No. of key pieces	Total No. of LWM pieces	Total LWM volume (yd^3)
Design	19	41	51.4
Targets	**19**	**65**	**220.3**
	on target	deficit	deficit

[a] includes length through crossing, regardless of structure type

[b] choose one of the following Forest Regions in the drop-down menu (if in doubt ask HQ Biology). See also the Forest Region tab for additional information

Western Washington lowla (generally <4,200 ft. in elevation west of the Cascade Crest)
Alpine (generally > 4,200 ft. in elevation and down to ~3,700 ft. in elevation east of the Cascade crest)
Douglas fir-Ponderosa pine (mainly east slope Cascades below 3,700 ft. elevation)

[c]LWM (Large Woody Material), also known as LWD (Large Woody Debris) is defined as a piece of wood at least 10 cm (4") diam. X 2 m (6ft) long (Fox 2001).

[d]includes rootwad if present

Key piece volume	
BFW class (ft)	volume (yd3)
0-16	1.31
17-33	3.28
34-49	7.86
50-66	11.79
67-98	12.77
99-164	13.76
165-328	14.08

adapted from Fox and Bolton (2007), Table 5

Key Piece density lookup table		
Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-33	0.0335
	34-328	0.0122
Alpine	0-49	0.0122
	50-164	0.0030
Douglas Fir/Pond. Pine (much of eastern WA)	0-98	0.0061

adapted from Fox and Bolton (2007), Table 4

Total Wood Volume lookup table		
Habitat zone	BFW class (feet)	75th percentile (yd3/ft stream)
Western WA	0-98	0.3948
	99-328	1.2641
Alpine	0-10	0.0399
	11-164	0.1196
Douglas Fir/Pond. Pine	0-98	0.0598

adapted from Fox and Bolton (2007), Table 4

Number of LWM pieces lookup table		
Habitat zone	BFW class (feet)	75th percentile (per/ft stream)
Western WA	0-20	0.1159
	21-98	0.1921
	99-328	0.6341
Alpine	0-10	0.0854
	11-98	0.1707
	99-164	0.1921
Douglas Fir/Pond. Pine	0-20	0.0884
	21-98	0.1067

adapted from Fox and Bolton (2007), Table 4

WSDOT Large Woody Material for stream restoration metrics calculator

State Route# & MP	***SR 308 MP 1.15***	**Key piece volume**	***1.310***	*yd3*
Stream name	*Big Scandia Creek, Bridge Design*	**Key piece/ft**	***0.0335***	*per ft stream*
length of regrade[a]	*558* ft	**Total wood vol./ft**	***0.3948***	*yd3/ft stream*
Bankfull width	*13* ft	**Total LWM[c] pieces/ft stream**	***0.1159***	*per ft stream*
Habitat zone[b]	*Western WA*			

Taper coeff.	-0.01554
LF_{rw}	1.5
H_{dbh}	4.5

Log type	*Diameter at midpoint (ft)*	*Length(ft)[d]*	*Volume (yd^3/log)[d]*	*Rootwad?*	*Qualifies as key piece?*	*No. LWM pieces*	*Total wood volume (yd^3)*	DBH based on mid point diameter (ft)	$D_{root\ collar}$ (ft)	L/2-Lrw (ft)
A	2.00	*30*	3.49	**yes**	yes	11	38.40	2.12	2.19	12
B	1.50	*24*	1.57	**yes**	yes	21	32.99	1.58	1.65	9.75
C	1.50	*15*	0.98	**yes**	no	11	10.80	1.51	1.58	5.25
D	1	*10*	0.29	**no**	no	13	3.78	1.08	1.05	3.5
E	0.5	*10*	0.07	**no**	no	18	1.31	0.58	0.57	4.25
F			0.00				0.00		0.00	0
G			0.00				0.00		0.00	0
H			0.00				0.00		0.00	0
I			0.00				0.00		0.00	0
J			0.00				0.00		0.00	0
K			0.00				0.00		0.00	0
L			0.00				0.00		0.00	0
M			0.00				0.00		0.00	0
N			0.00				0.00		0.00	0
O			0.00				0.00		0.00	0
P			0.00				0.00		0.00	0

	No. of key pieces	Total No. of LWM pieces	Total LWM volume (yd^3)
Design	32	74	87.3
Targets	**19**	**65**	**220.3**
	surplus	surplus	deficit

[a] includes length through crossing, regardless of structure type

[b] choose one of the following Forest Regions in the drop-down menu (if in doubt ask HQ Biology). See also the Forest Region tab for additional information

Western Washington lowla (generally <4,200 ft. in elevation west of the Cascade Crest)
Alpine (generally > 4,200 ft. in elevation and down to ~3,700 ft. in elevation east of the Cascade crest)
Douglas fir-Ponderosa pine (mainly east slope Cascades below 3,700 ft. elevation)

[c]LWM (Large Woody Material), also known as LWD (Large Woody Debris) is defined as a piece of wood at least 10 cm (4") diam. X 2 m (6ft) long (Fox 2001).

[d]includes rootwad if present

Key piece volume	
BFW class (ft)	volume (yd3)
0-16	1.31
17-33	3.28
34-49	7.86
50-66	11.79
67-98	12.77
99-164	13.76
165-328	14.08

adapted from Fox and Bolton (2007), Table 5

Key Piece density lookup table		
Habitat zone	BFW class (feet)	75^{th} percentile (yd3/ft stream)
Western WA	0-33	0.0335
	34-328	0.0122
Alpine	0-49	0.0122
	50-164	0.0030
Douglas Fir/Pond. Pine (much of eastern WA)	0-98	0.0061

adapted from Fox and Bolton (2007), Table 4

Total Wood Volume lookup table		
Habitat zone	BFW class (feet)	75^{th} percentile (yd3/ft stream)
Western WA	0-98	0.3948
	99-328	1.2641
Alpine	0-10	0.0399
	11-164	0.1196
Douglas Fir/Pond. Pine	0-98	0.0598

adapted from Fox and Bolton (2007), Table 4

Number of LWM pieces lookup table		
Habitat zone	BFW class (feet)	75^{th} percentile (per/ft stream)
Western WA	0-20	0.1159
	21-98	0.1921
	99-328	0.6341
Alpine	0-10	0.0854
	11-98	0.1707
	99-164	0.1921
Douglas Fir/Pond. Pine	0-20	0.0884
	21-98	0.1067

adapted from Fox and Bolton (2007), Table 4

Appendix G: Future Projections for Climate-Adapted Culvert Design

Future Projections for Climate-Adapted Culvert Design

Project Name:

Stream Name:

Drainage Area: 33 ac

Projected mean percent change in bankfull flow:

2040s: 14.4%

2080s: 17.4%

Projected mean percent change in bankfull width:

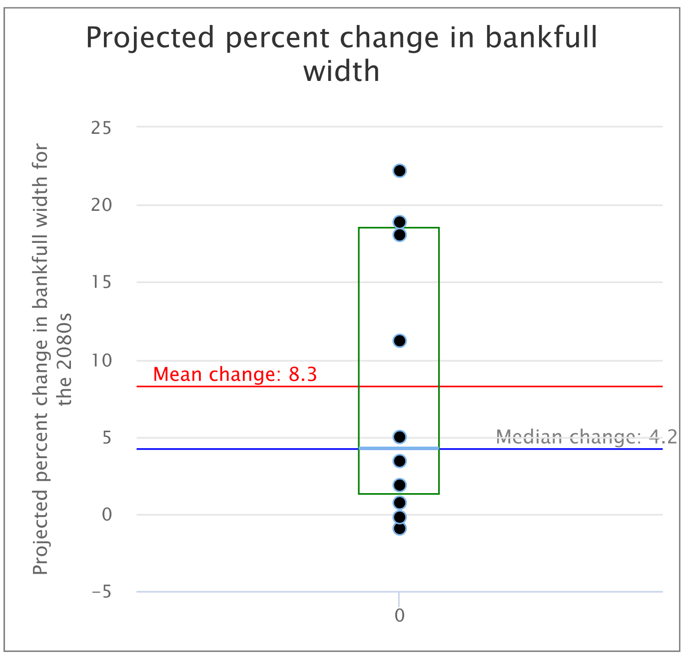
2040s: 6.9%

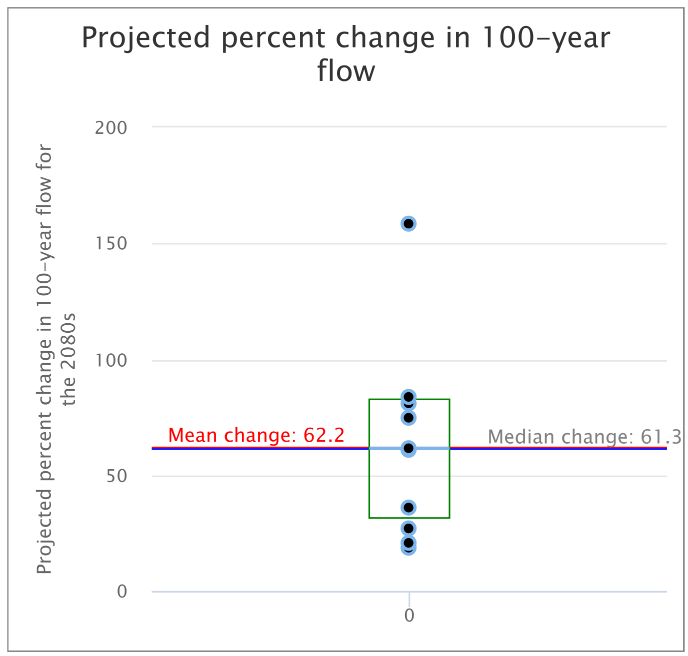
2080s: 8.3%

Projected mean percent change in 100-year flood:

2040s: 45.2%

2080s: 62.2%





Black dots are projections from 10 separate models

Appendix H: SRH-2D Model Results

Existing Conditions SRH-2D Results

Planview

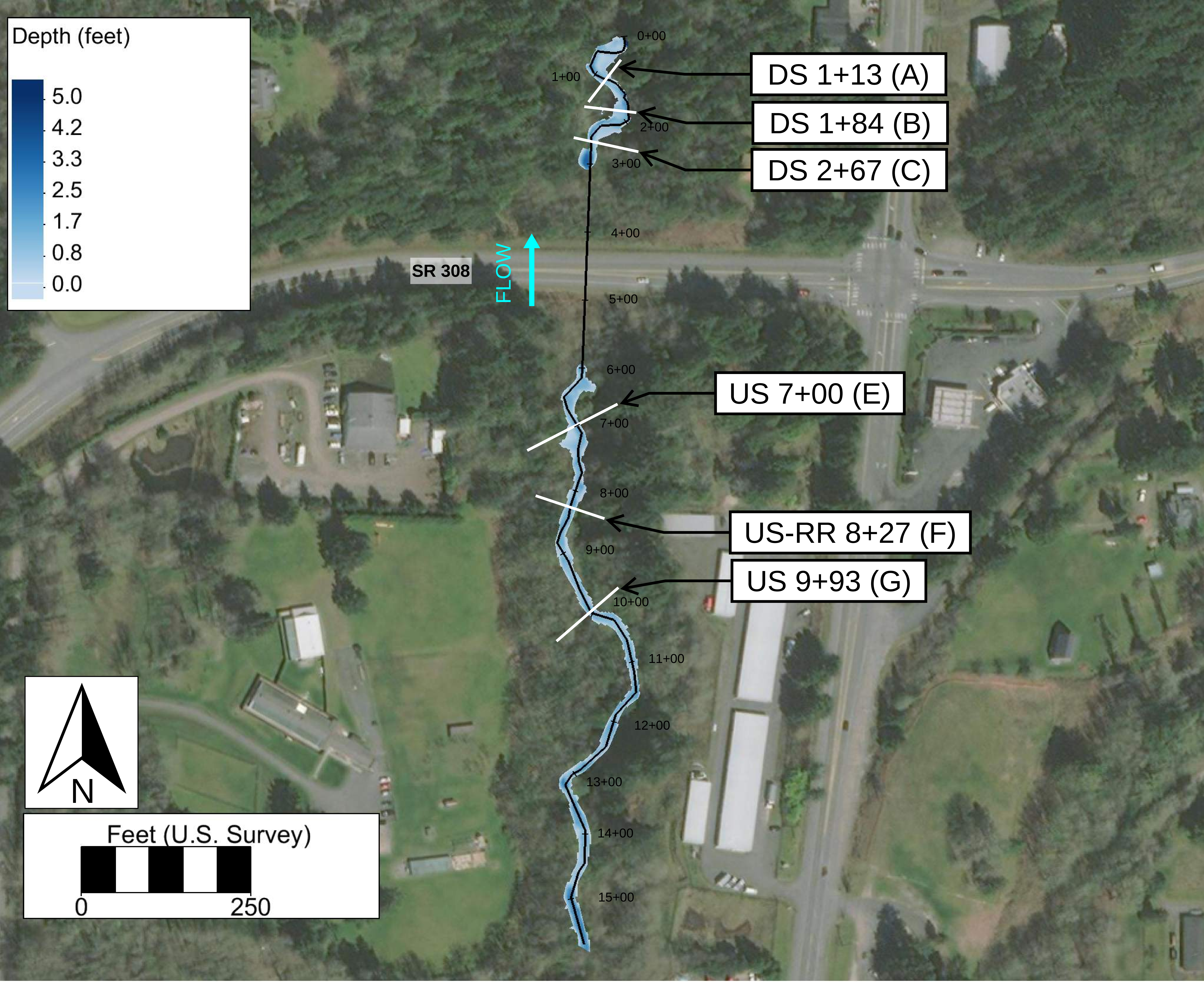


Figure H.1: Existing conditions 2-year depth

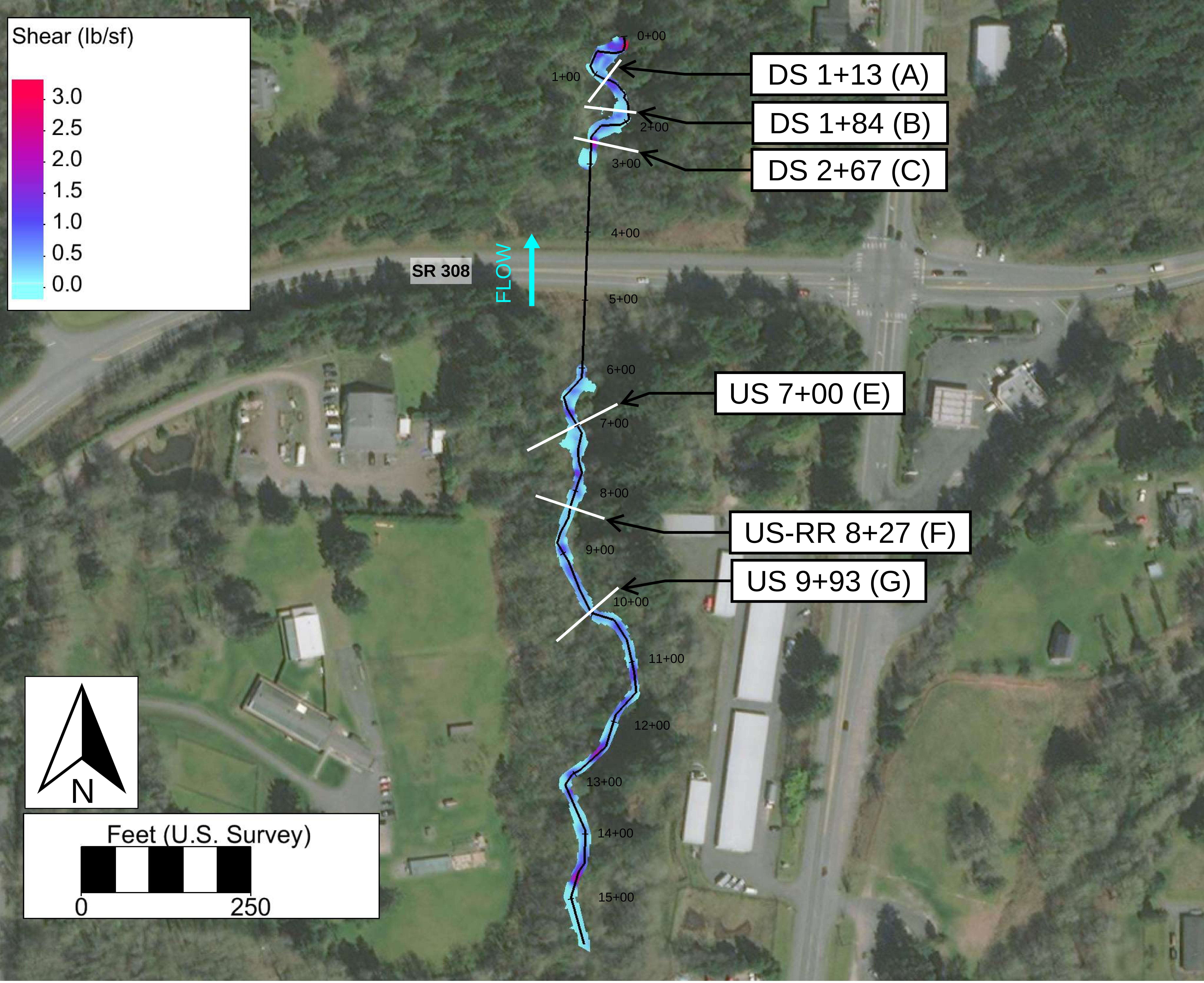


Figure H.2: Existing conditions 2-year shear stress

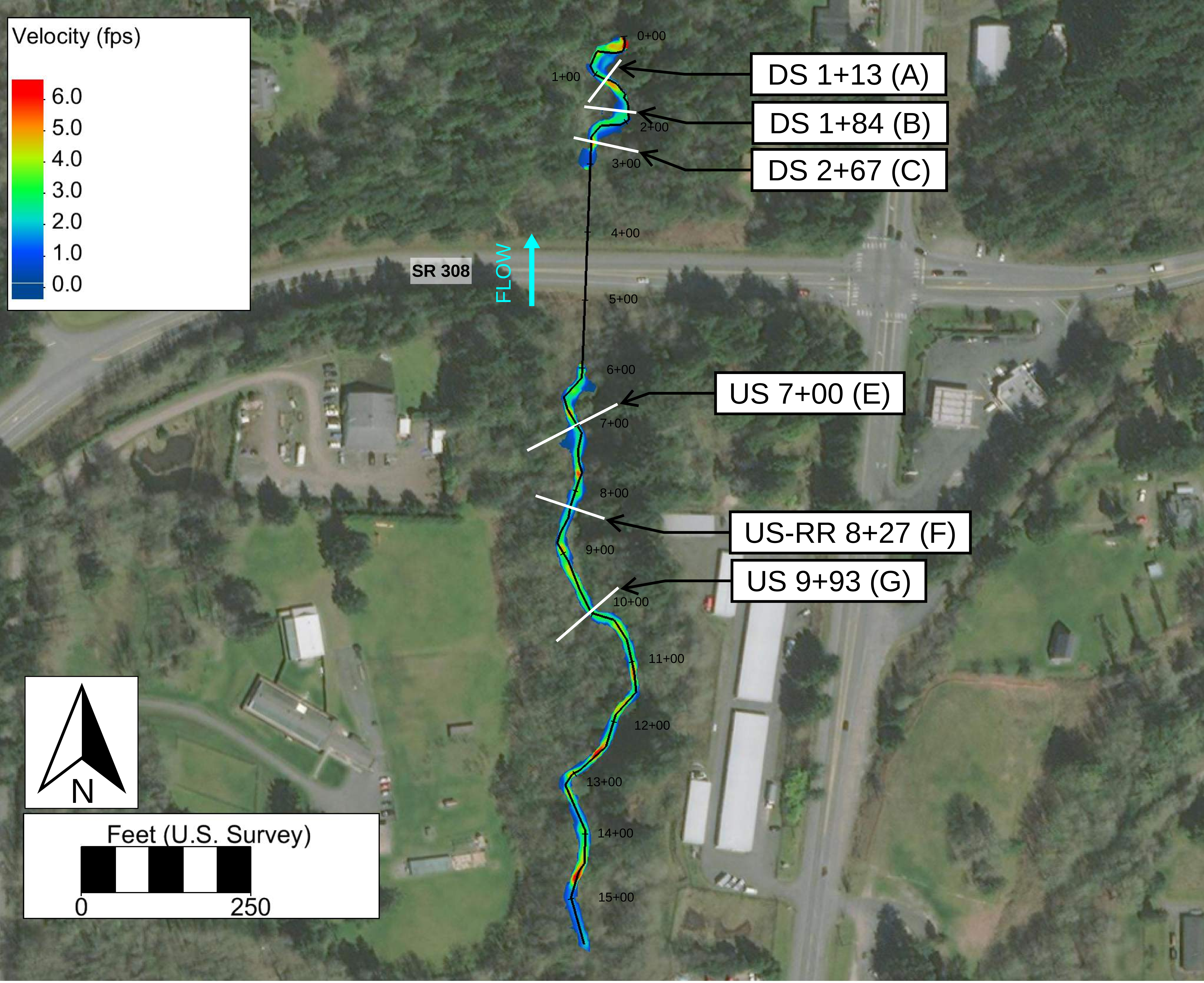


Figure H.3: Existing conditions 2-year velocity

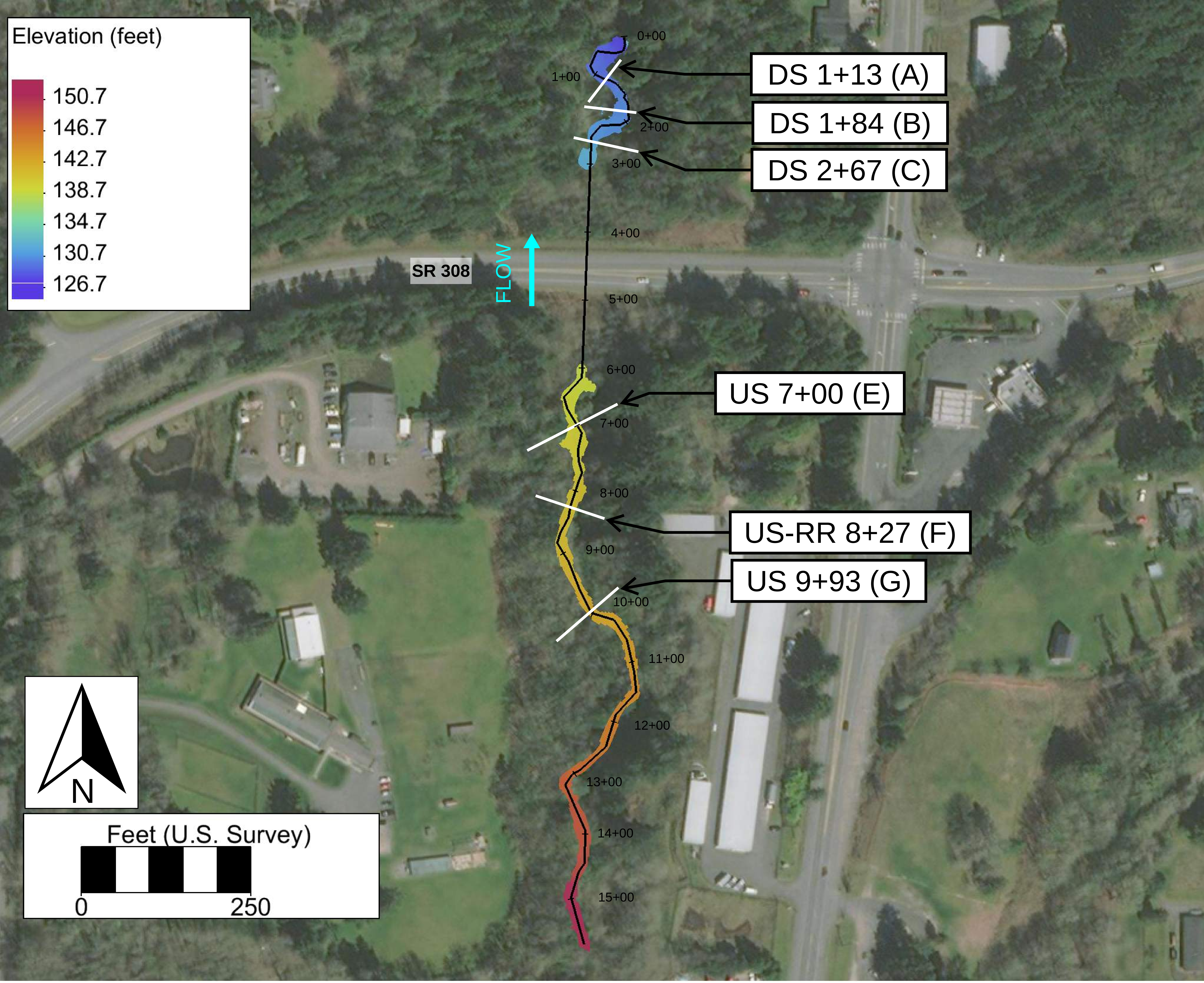


Figure H.4: Existing conditions 2-year water surface elevation

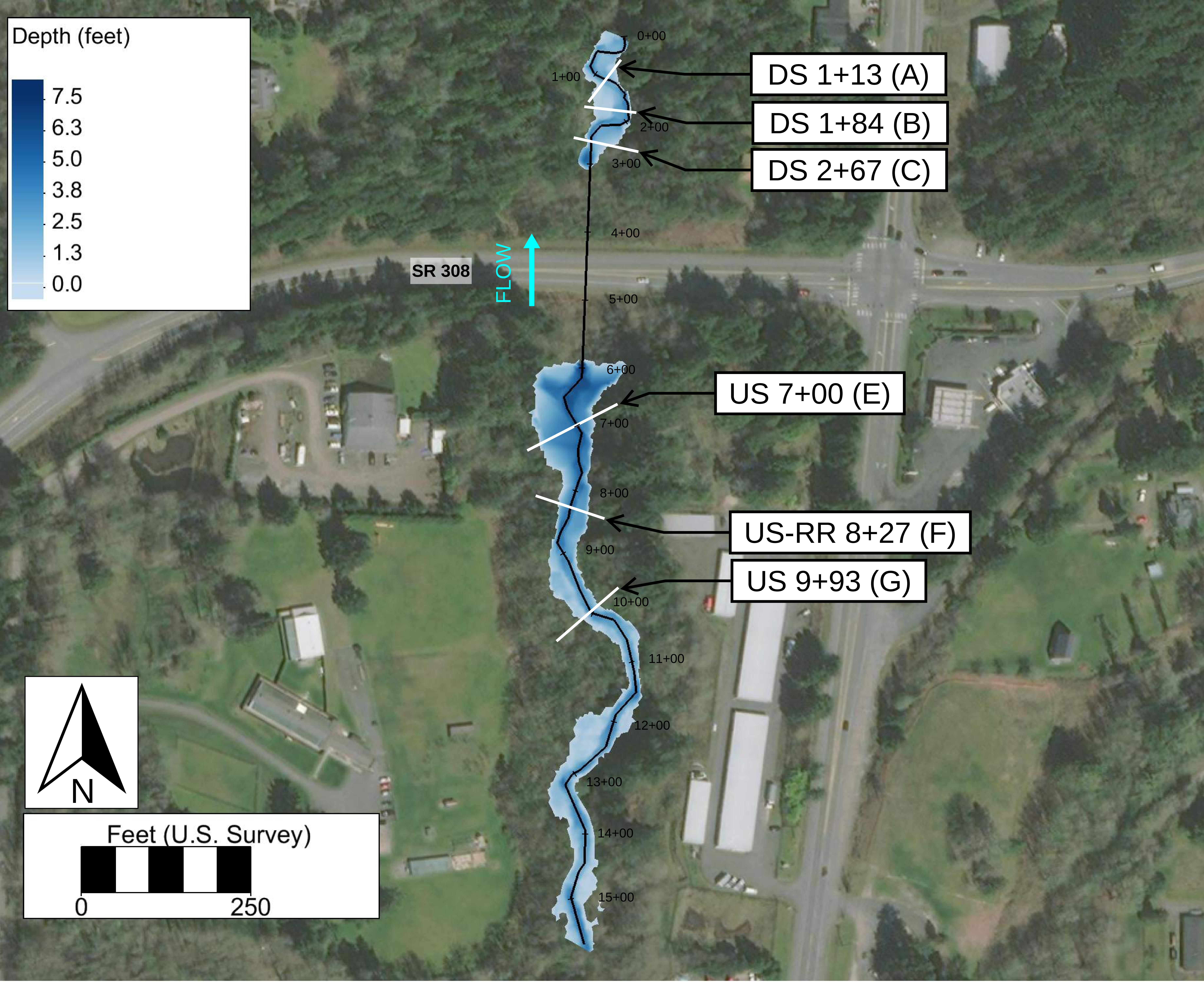


Figure H.5: Existing conditions 100-year depth

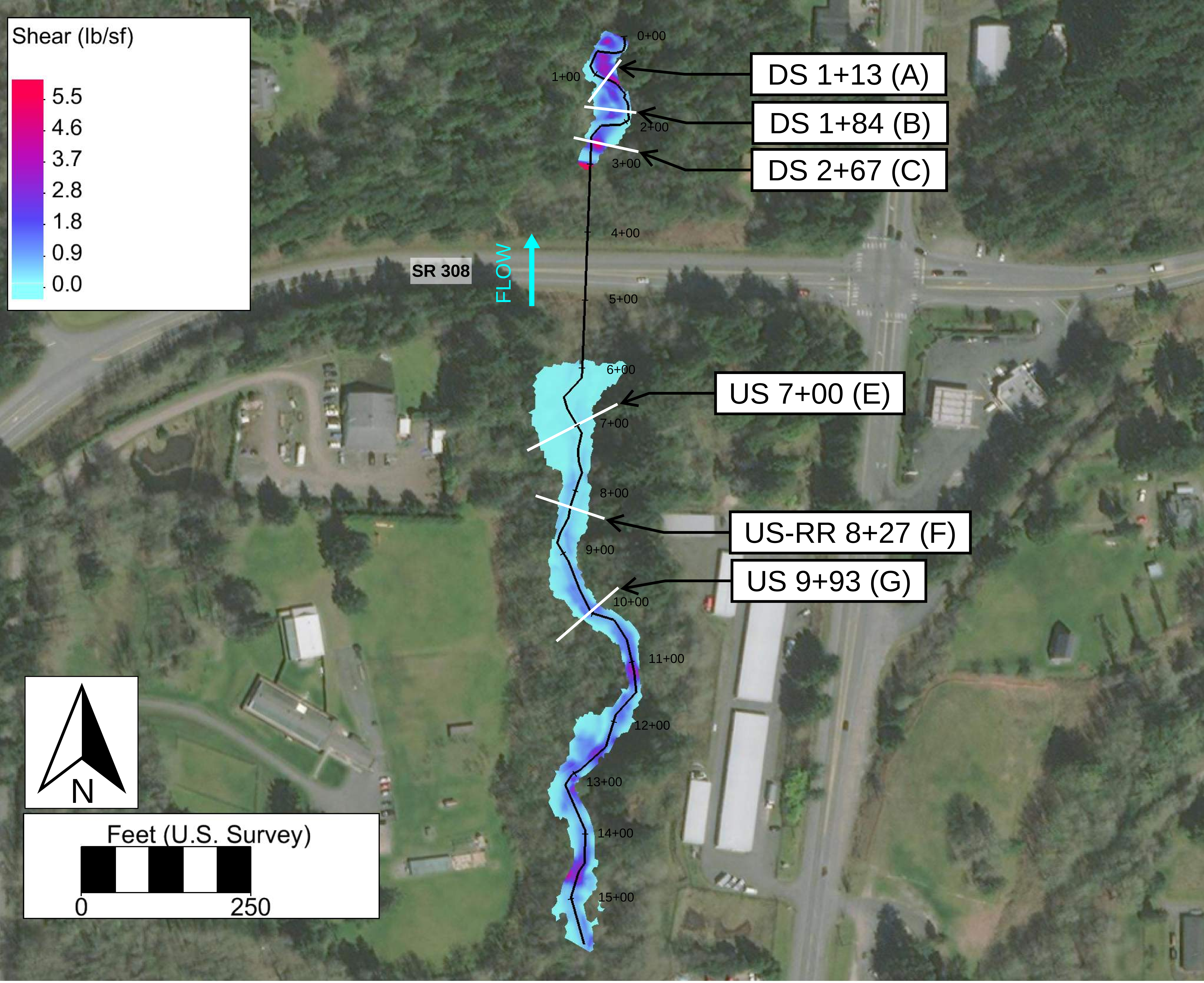


Figure H.6: Existing conditions 100-year shear stress

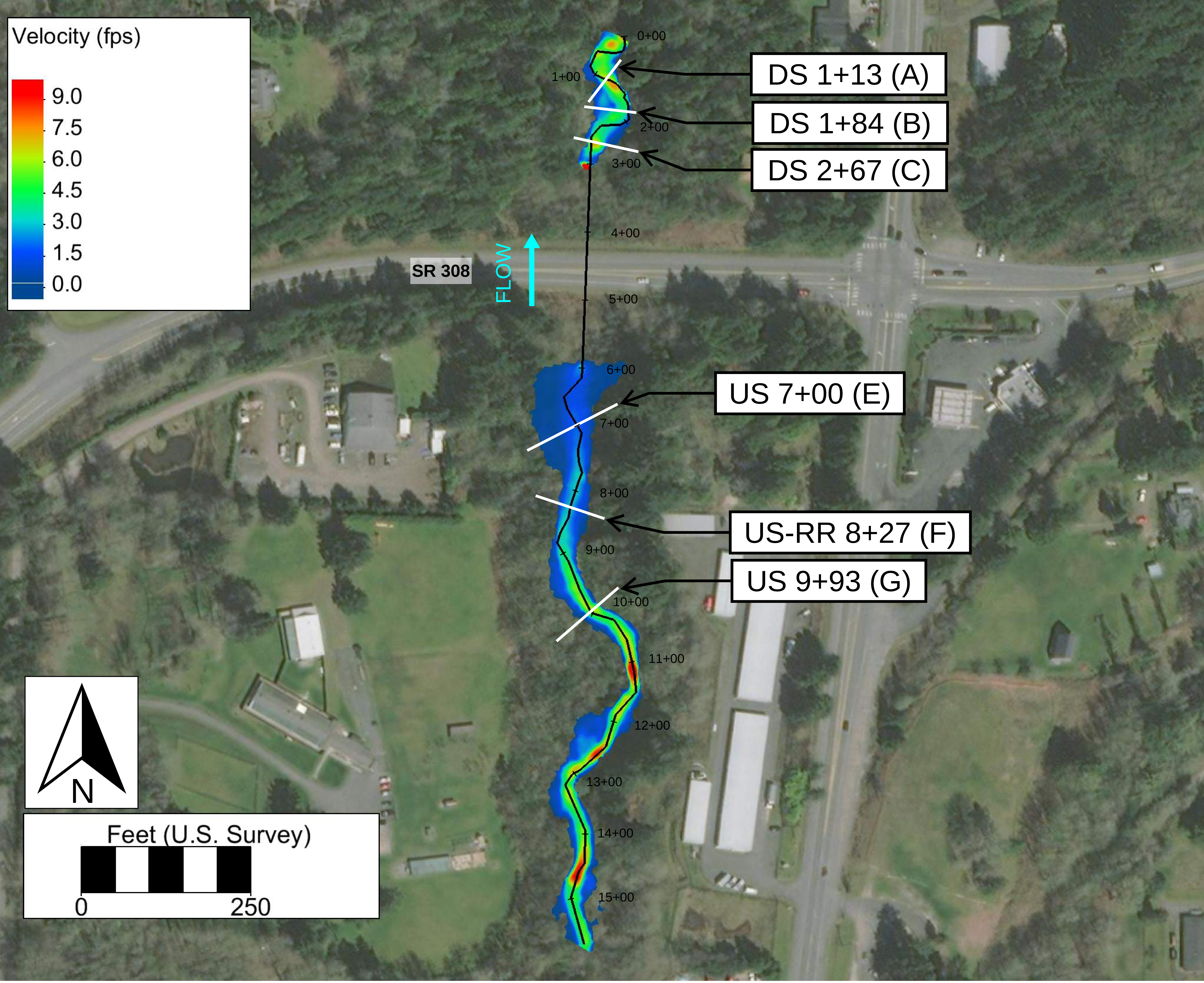


Figure H.7: Existing conditions 100-year velocity

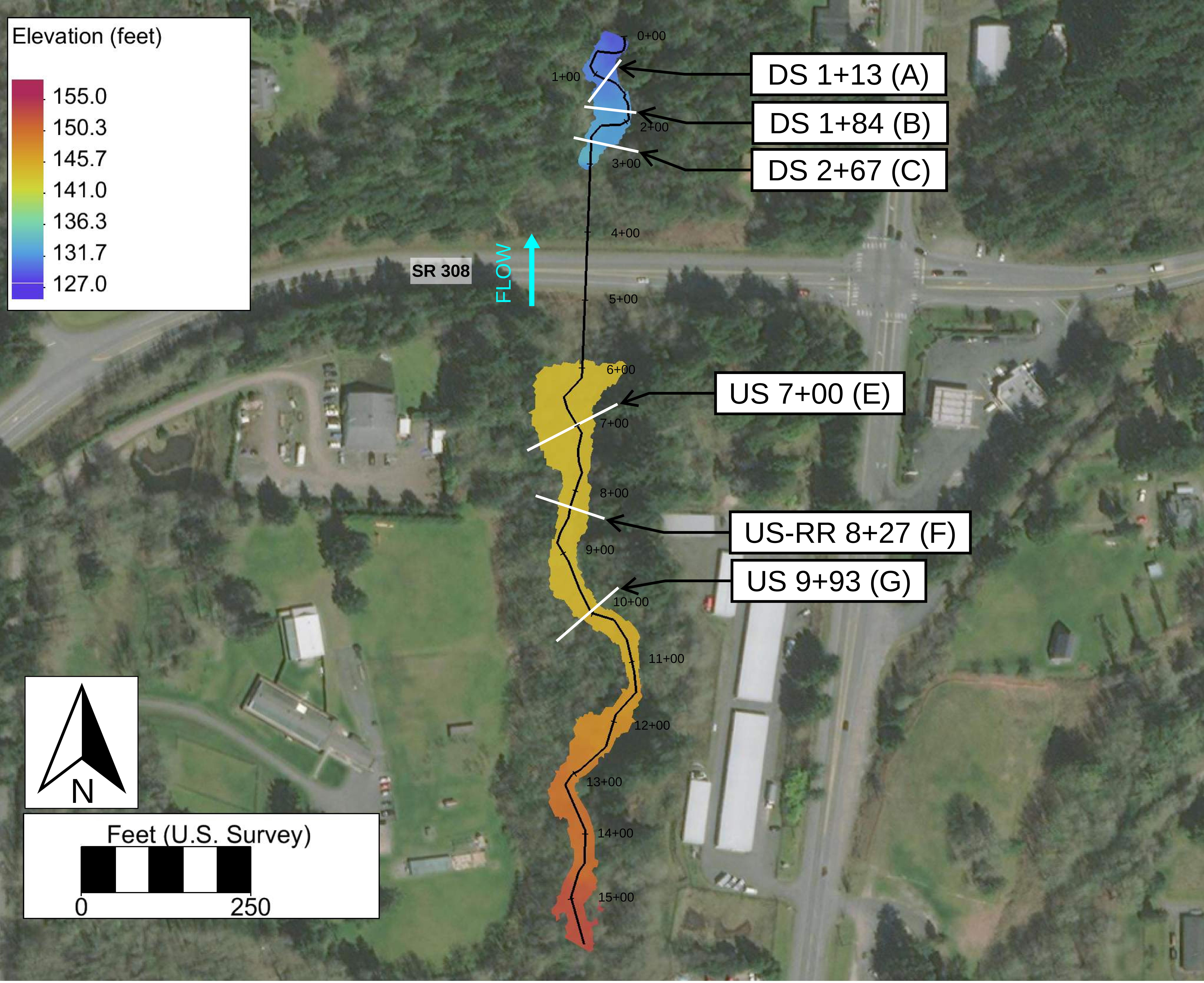


Figure H.8: Existing conditions 100-year water surface elevation

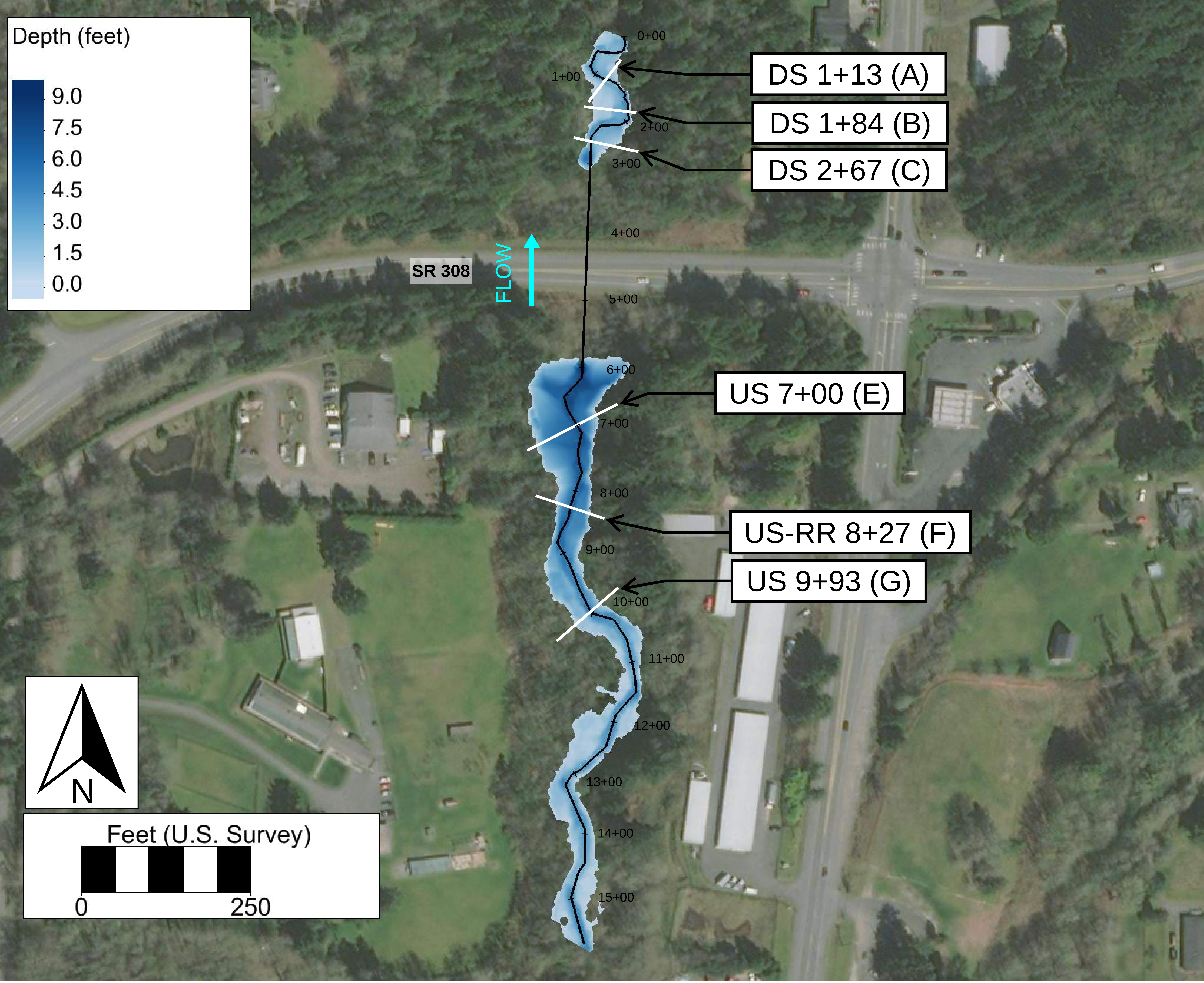


Figure H.9: Existing conditions 500-year depth

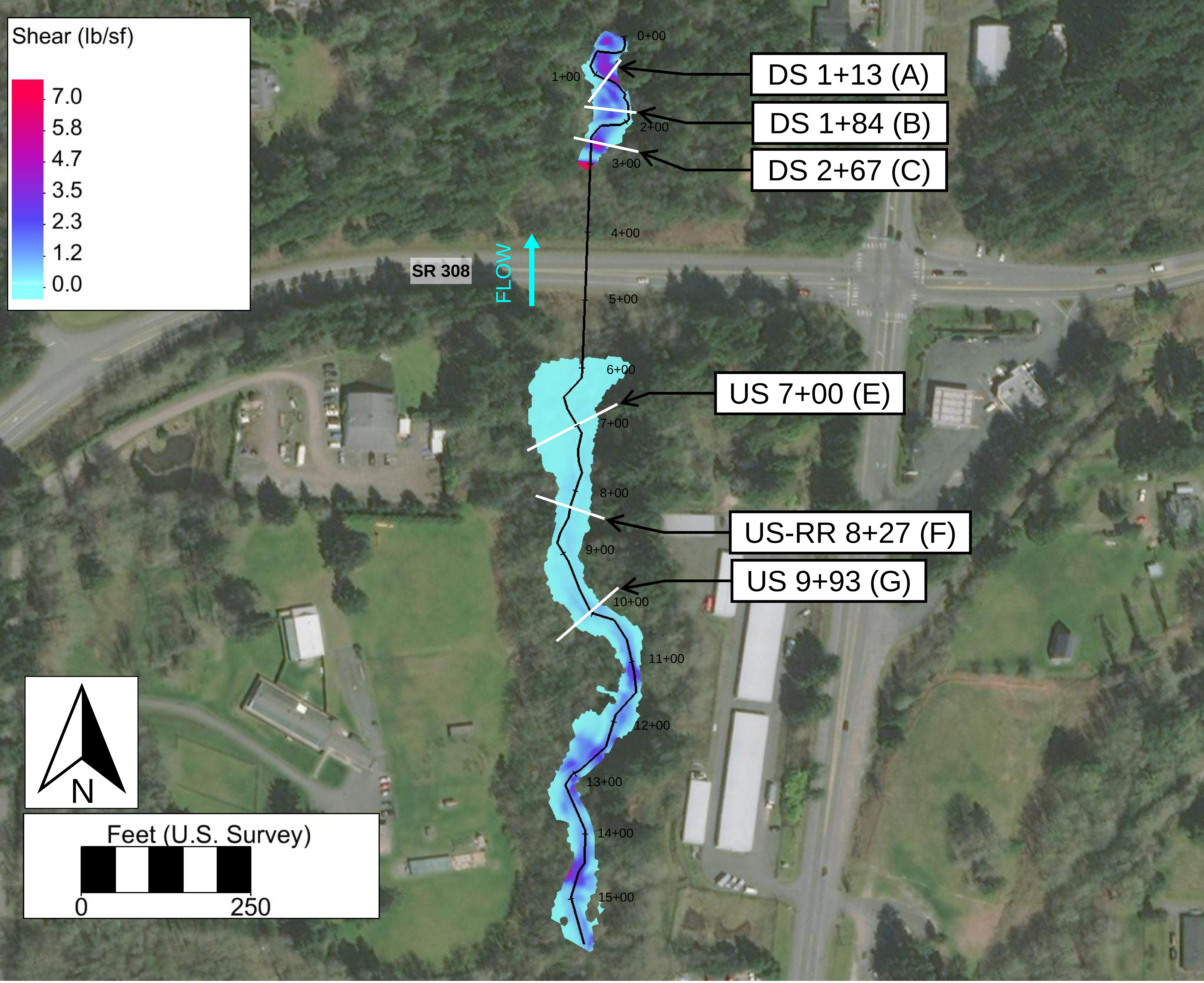


Figure H.10: Existing conditions 500-year shear stress

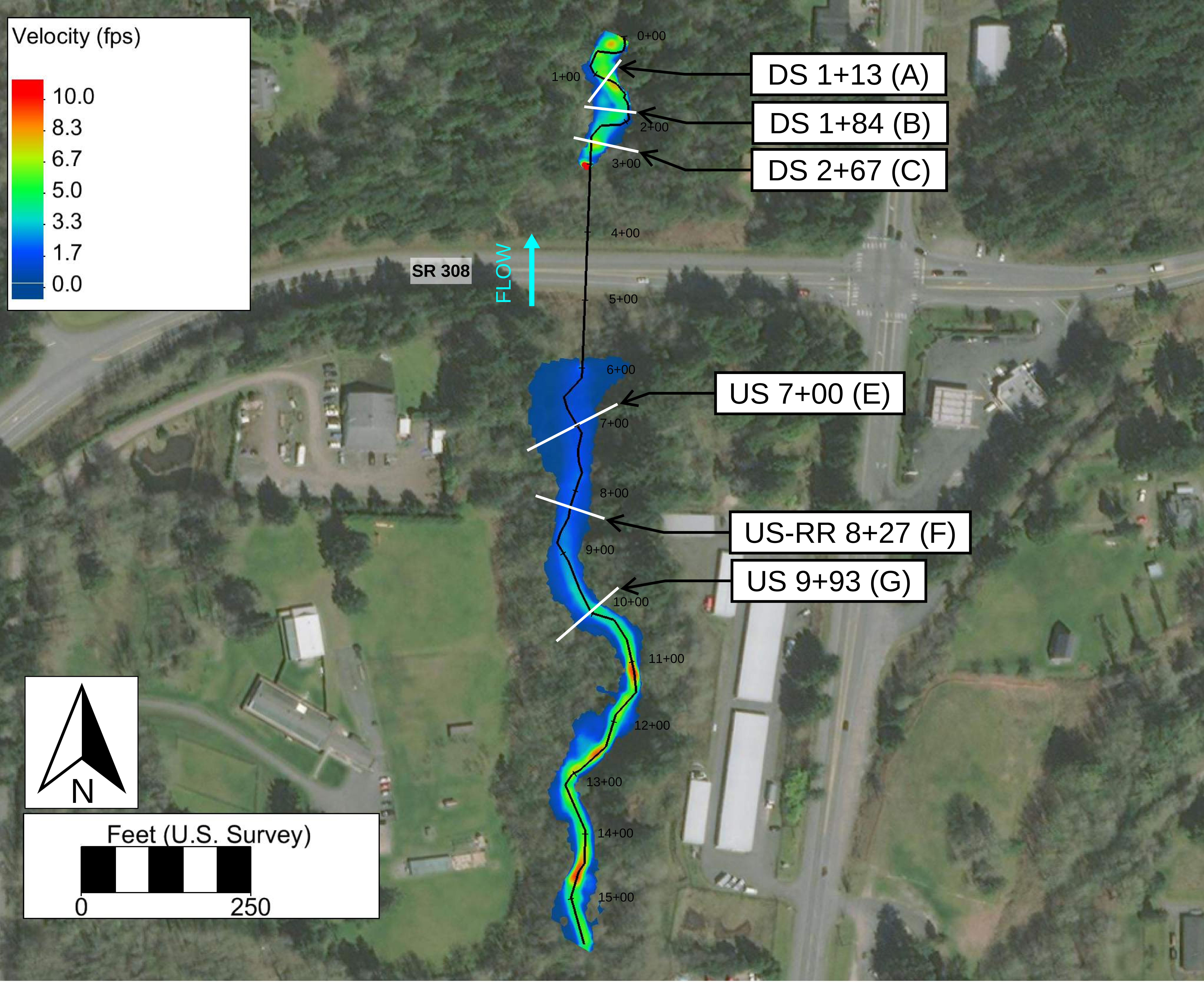


Figure H.11: Existing conditions 500-year velocity

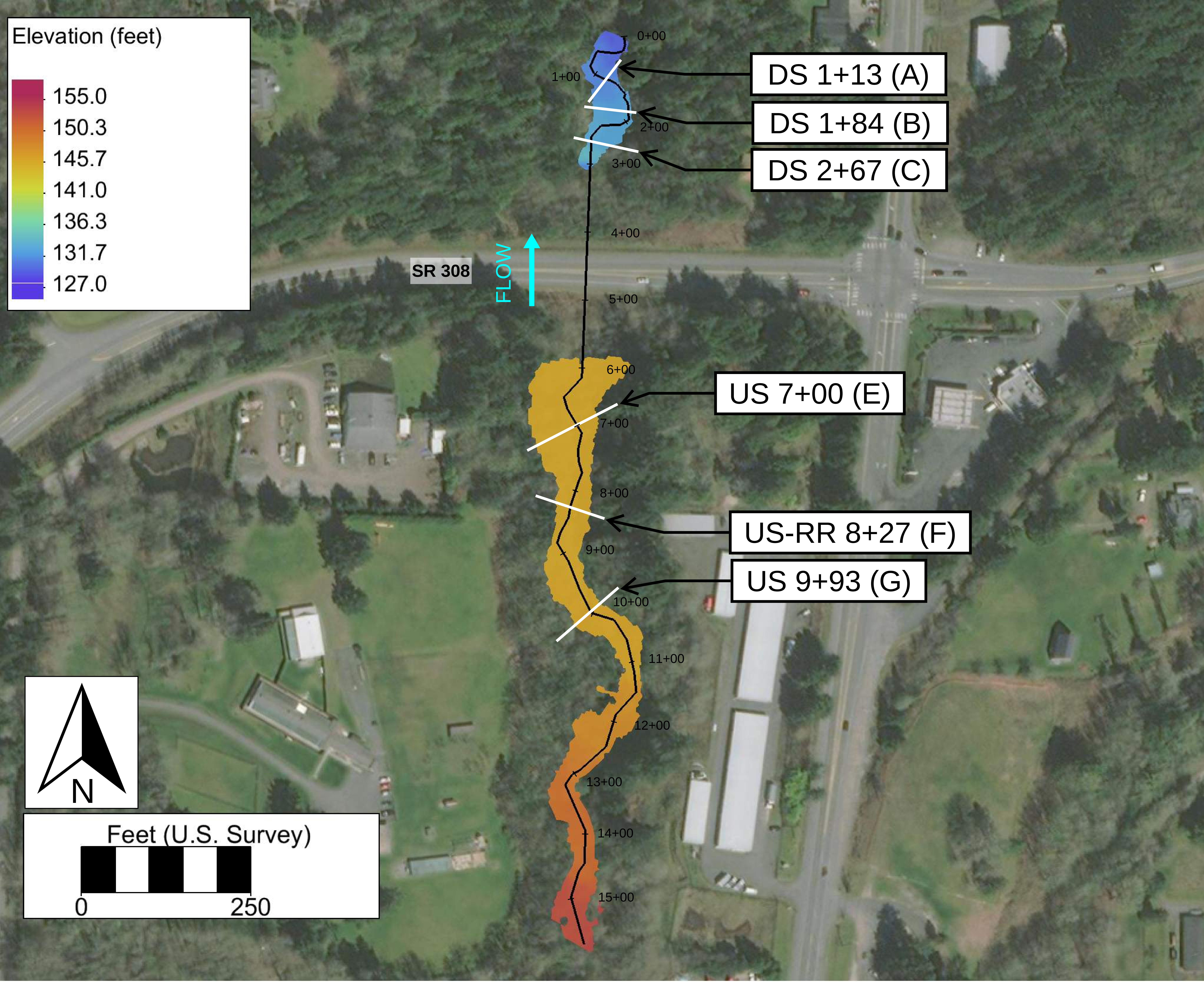


Figure H.12: Existing conditions 500-year water surface elevation

Natural Conditions SRH-2D Results

Planview

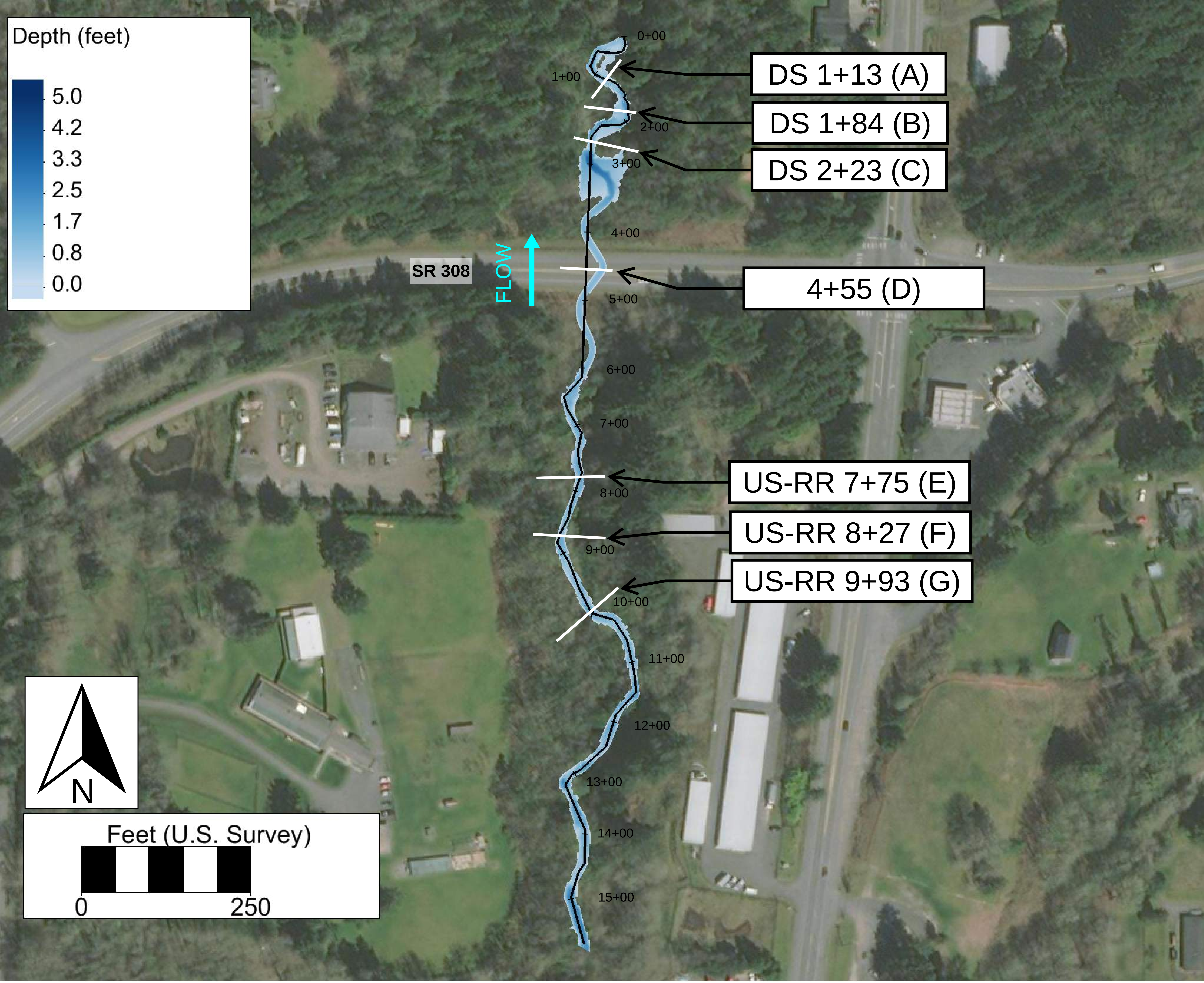


Figure H.13: Natural conditions 2-year depth

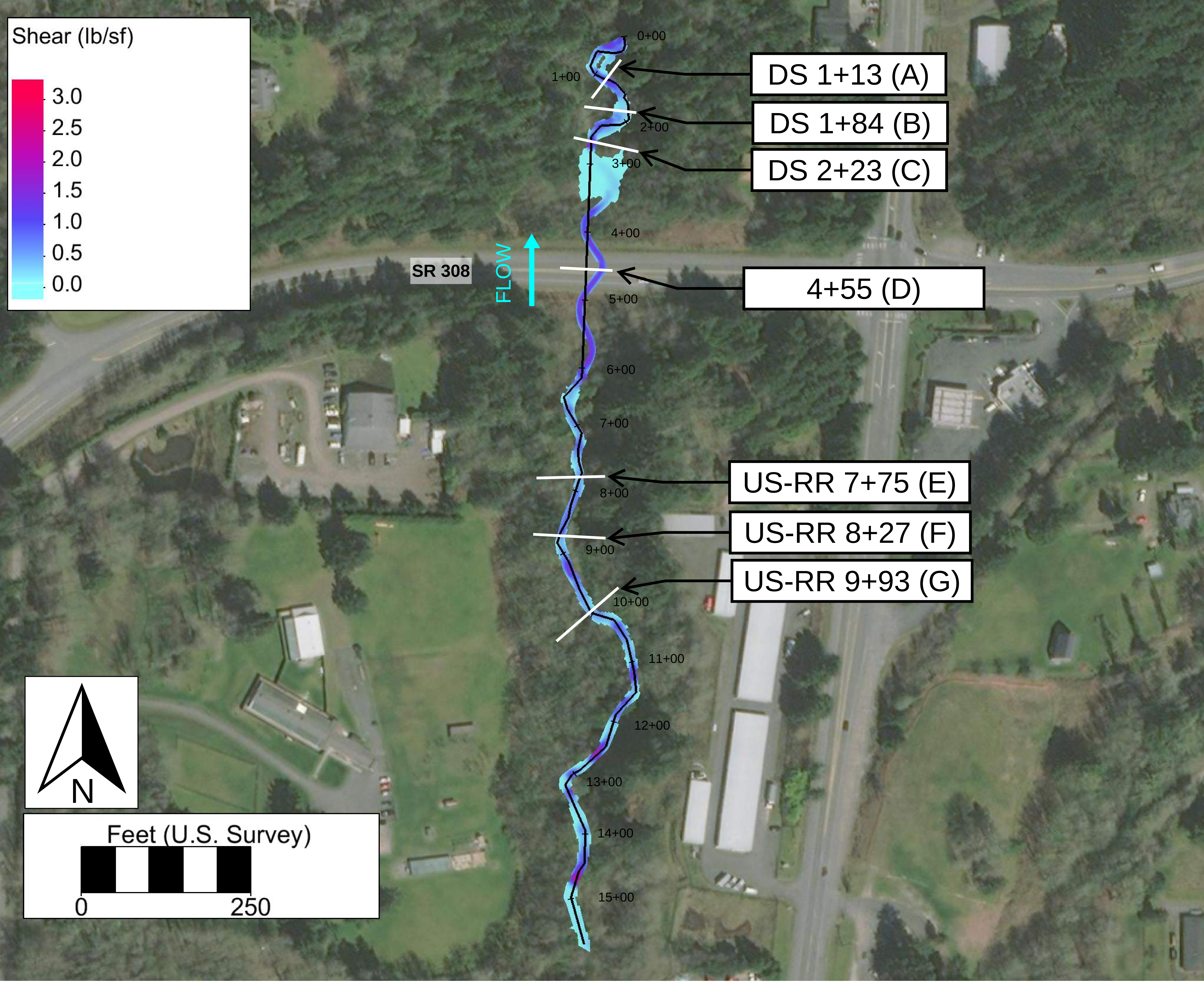


Figure H.14: Natural conditions 2-year shear stress

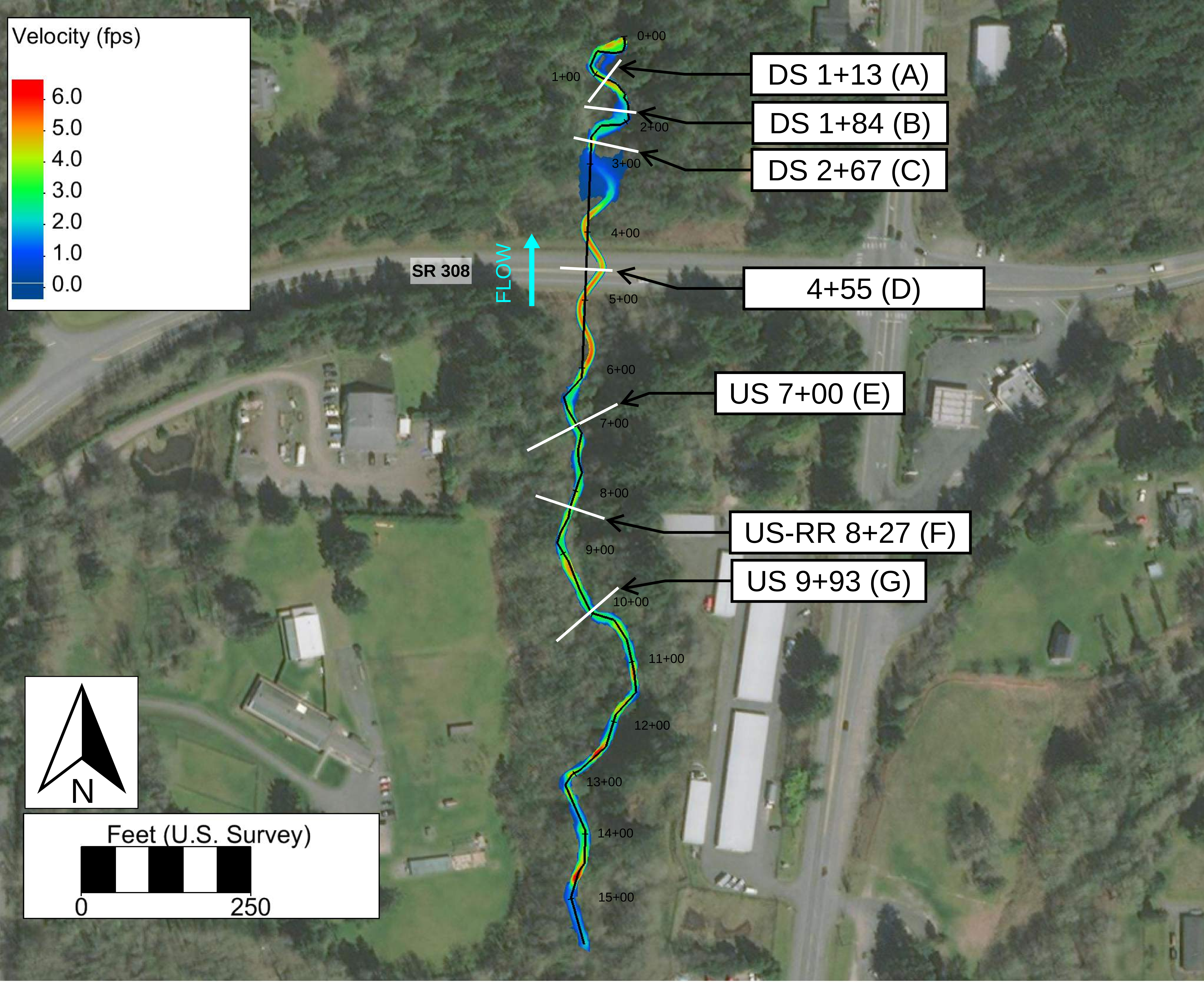


Figure H.15: Natural conditions 2-year velocity

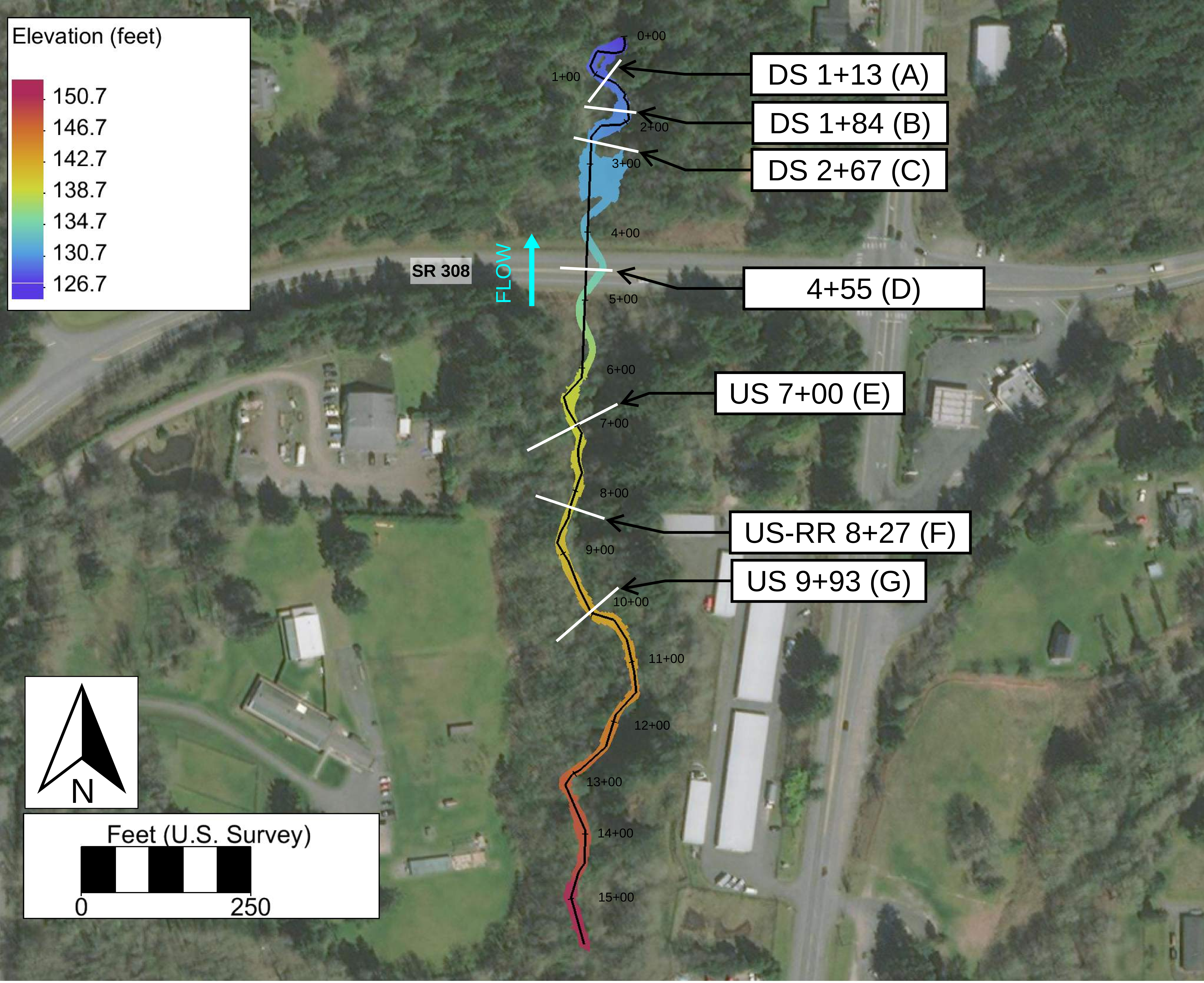


Figure H.16: Natural conditions 2-year water surface elevation

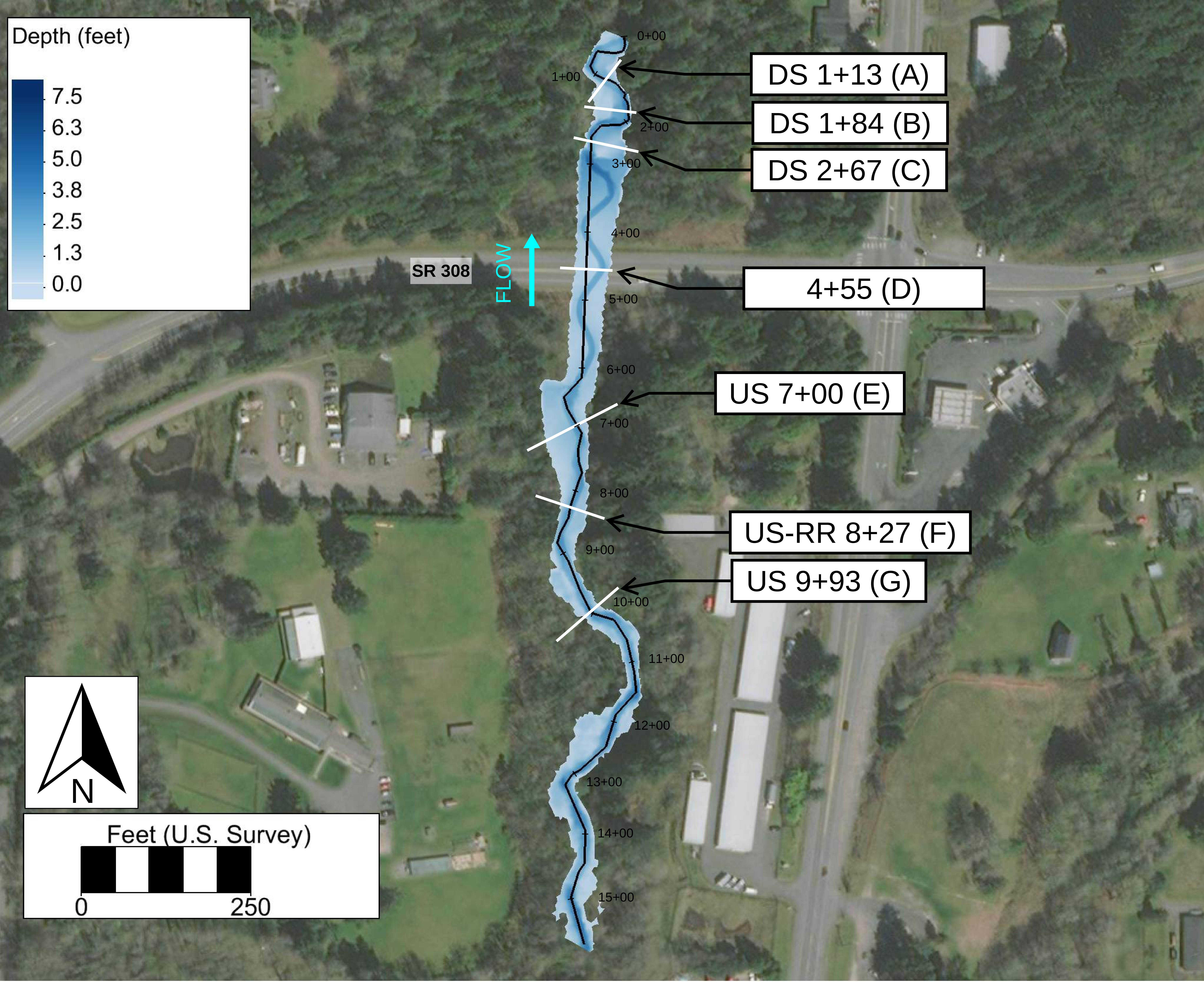


Figure H.17: Natural conditions 100-year depth

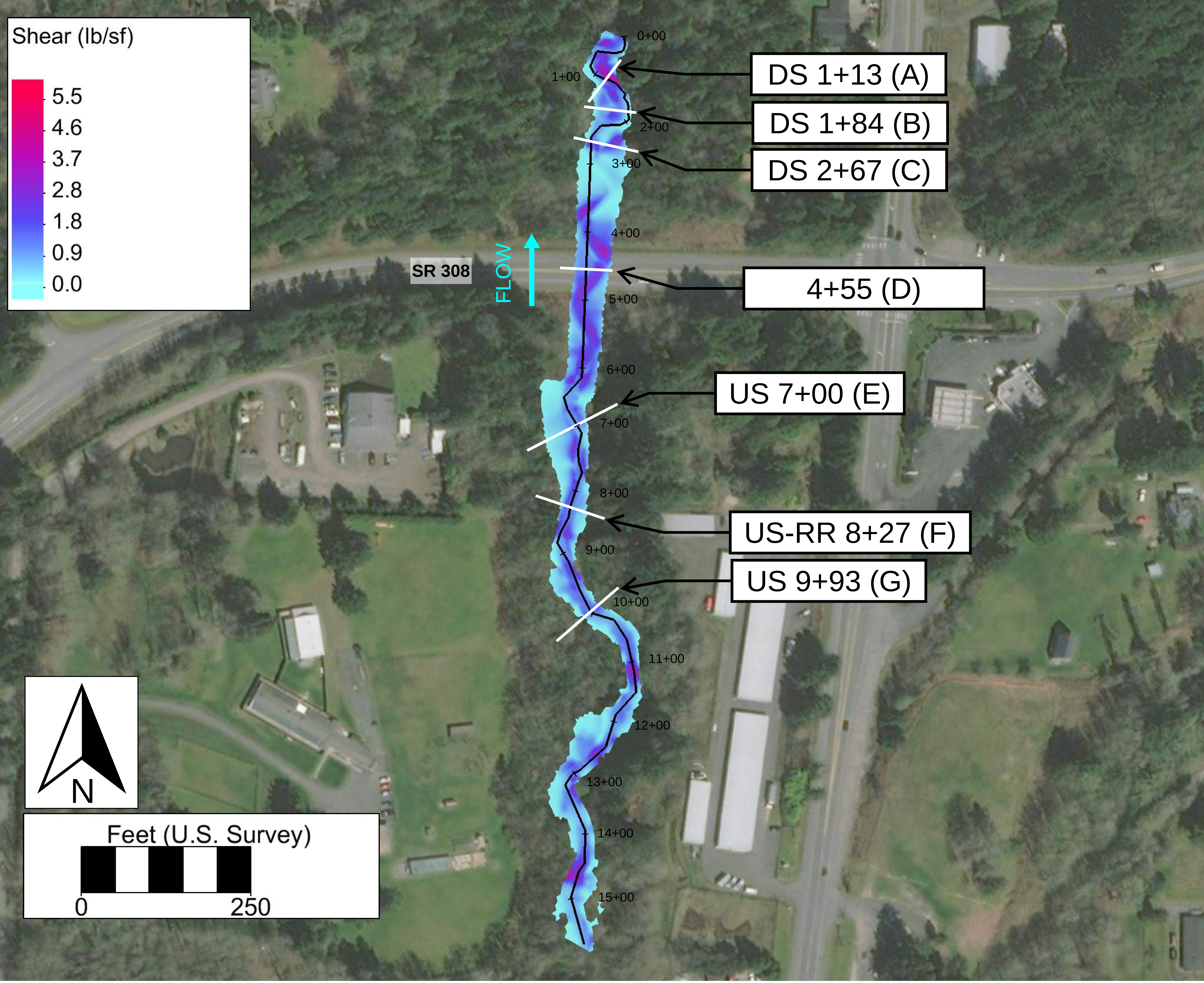


Figure H.18: Natural conditions 100-year shear stress

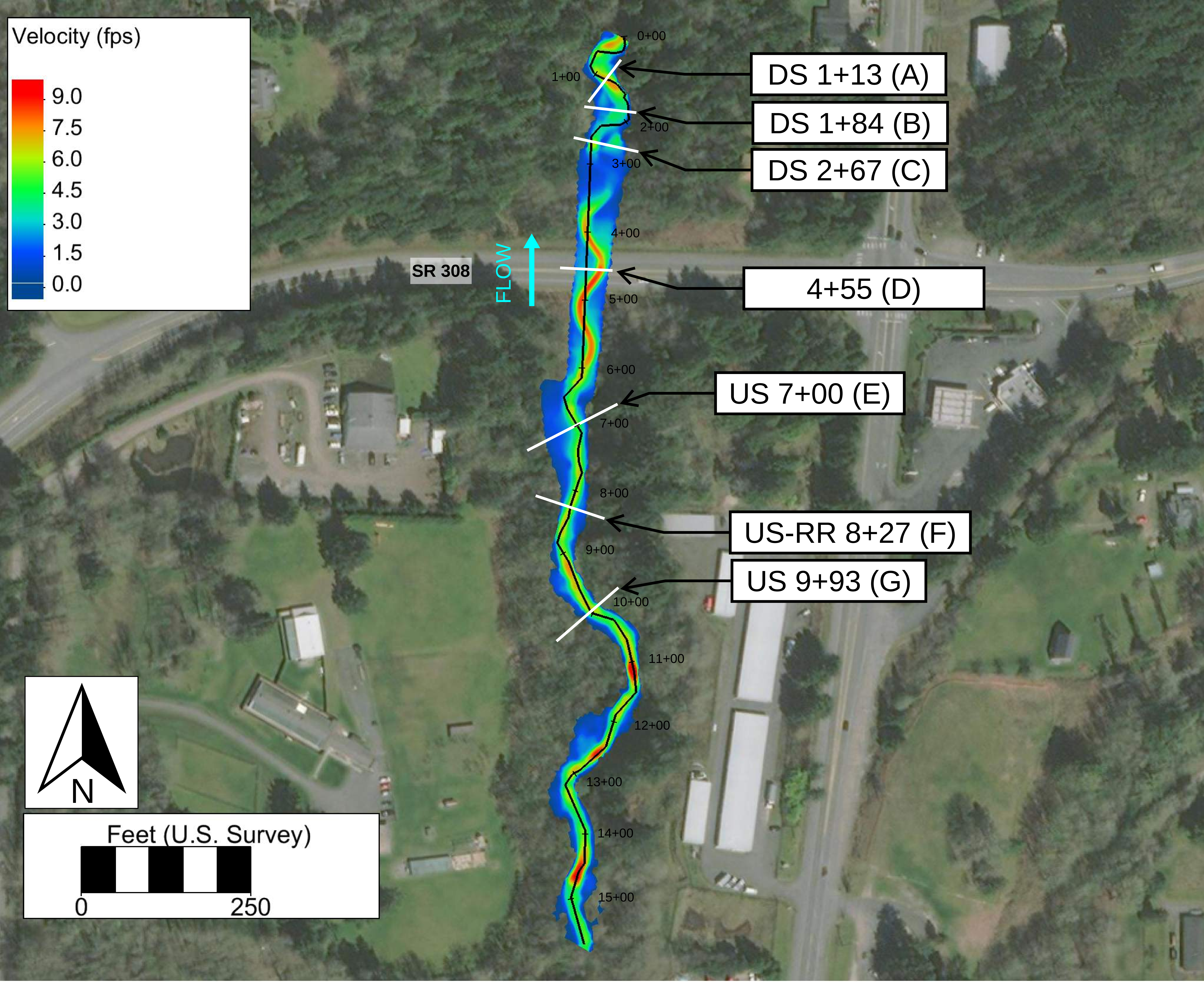


Figure H.19: Natural conditions 100-year velocity

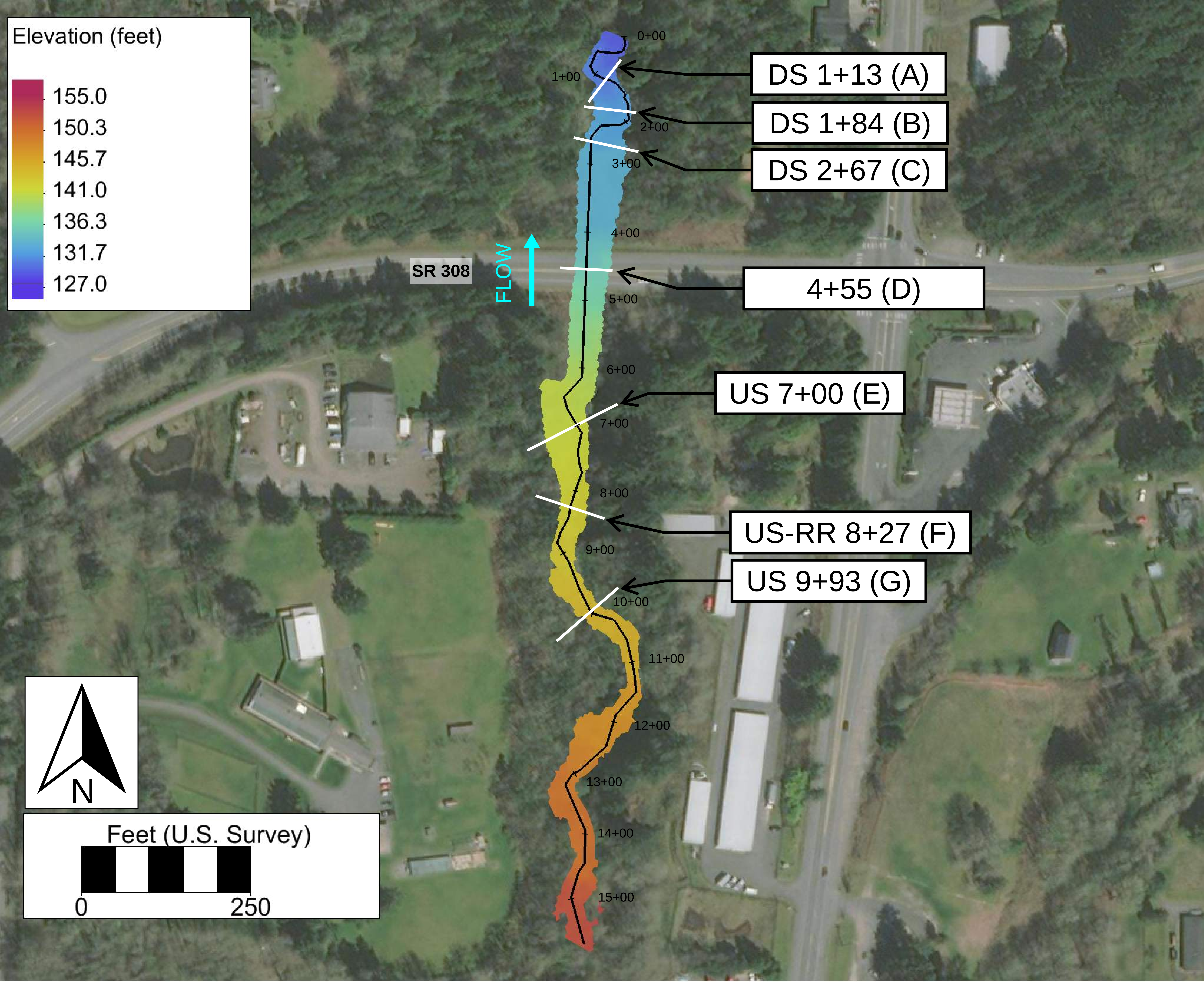


Figure H.20: Natural conditions 100-year water surface elevation

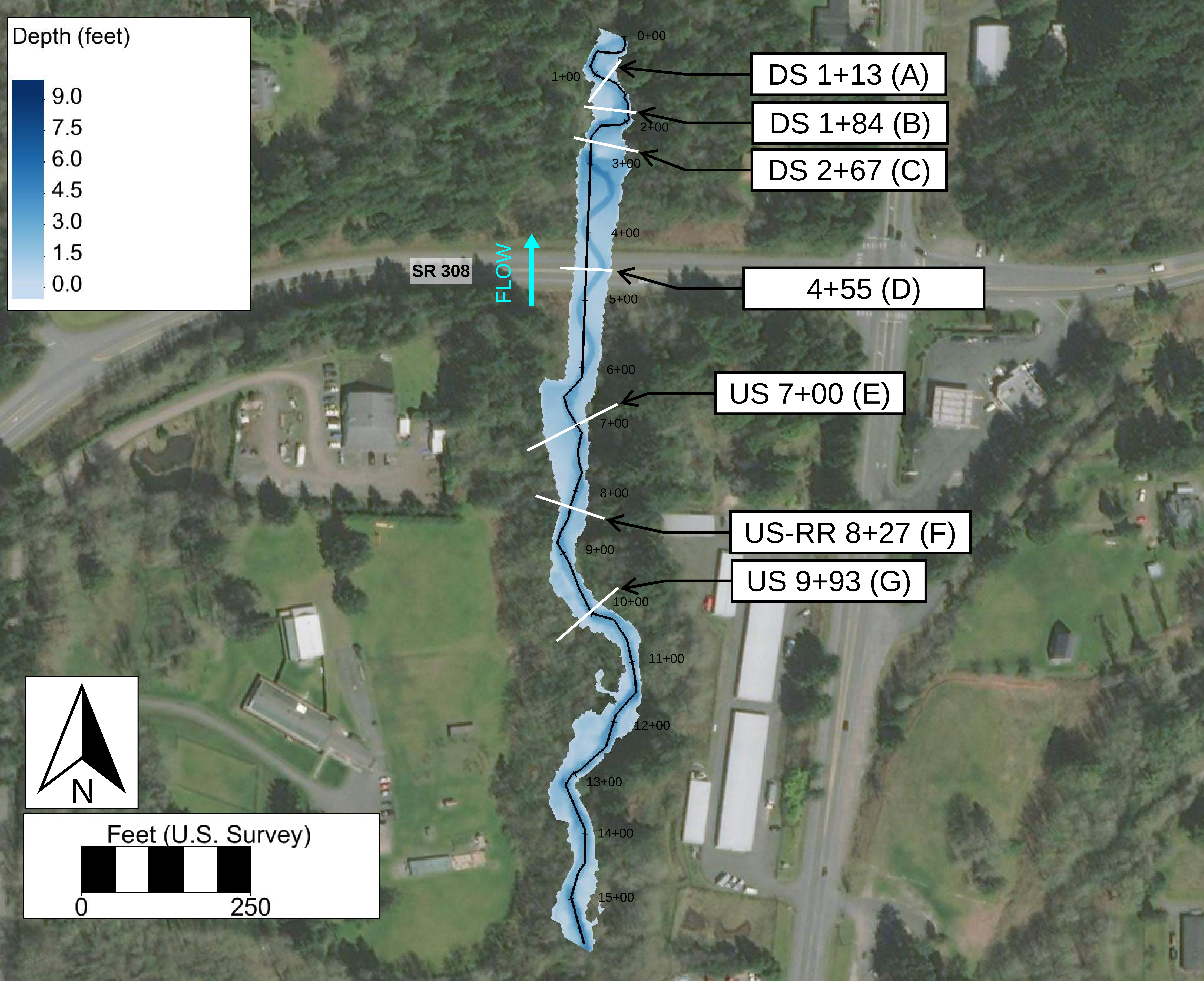


Figure H.21: Natural conditions 500-year depth

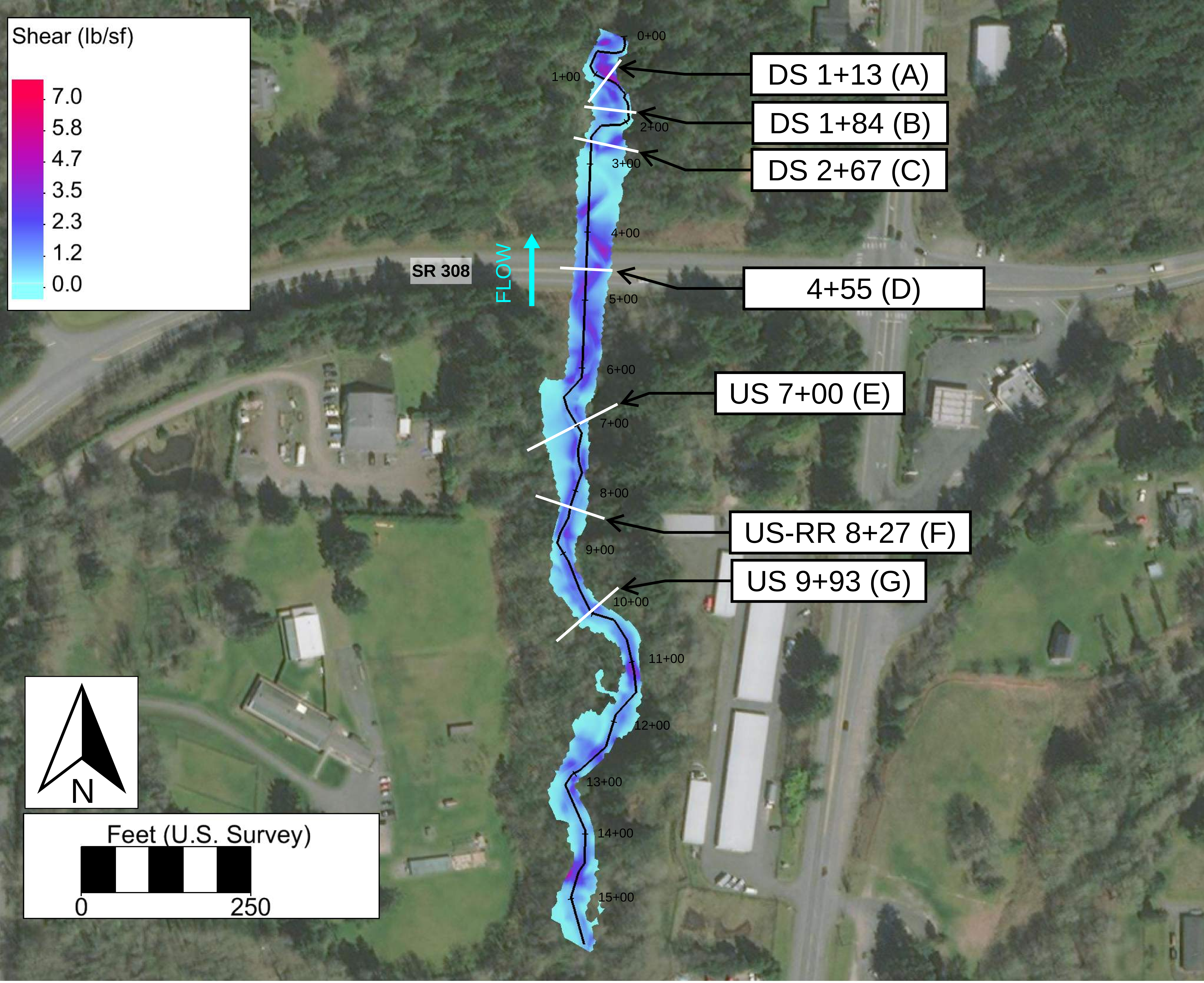


Figure H.22: Natural conditions 500-year shear stress

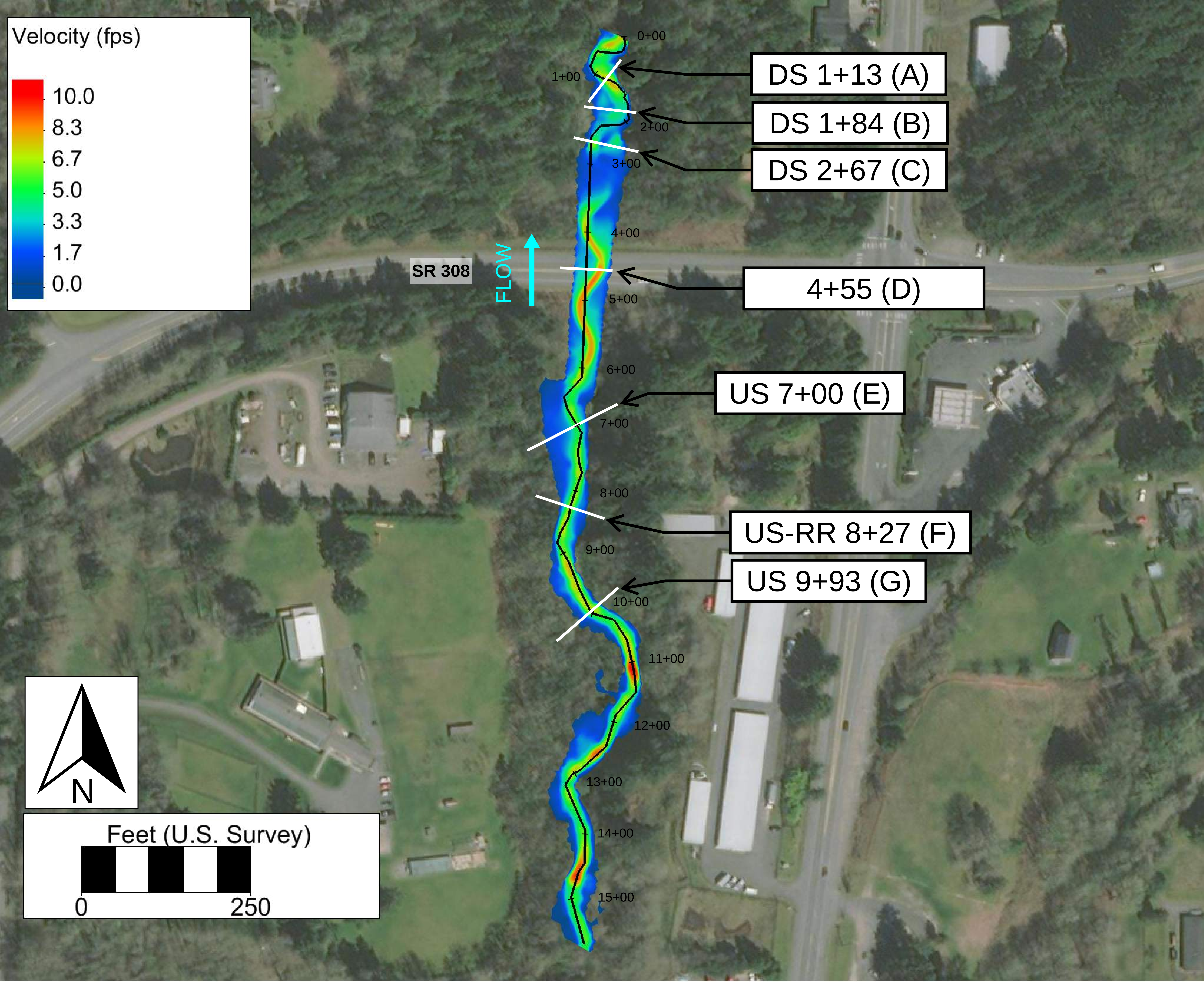


Figure H.23: Natural conditions 500-year velocity

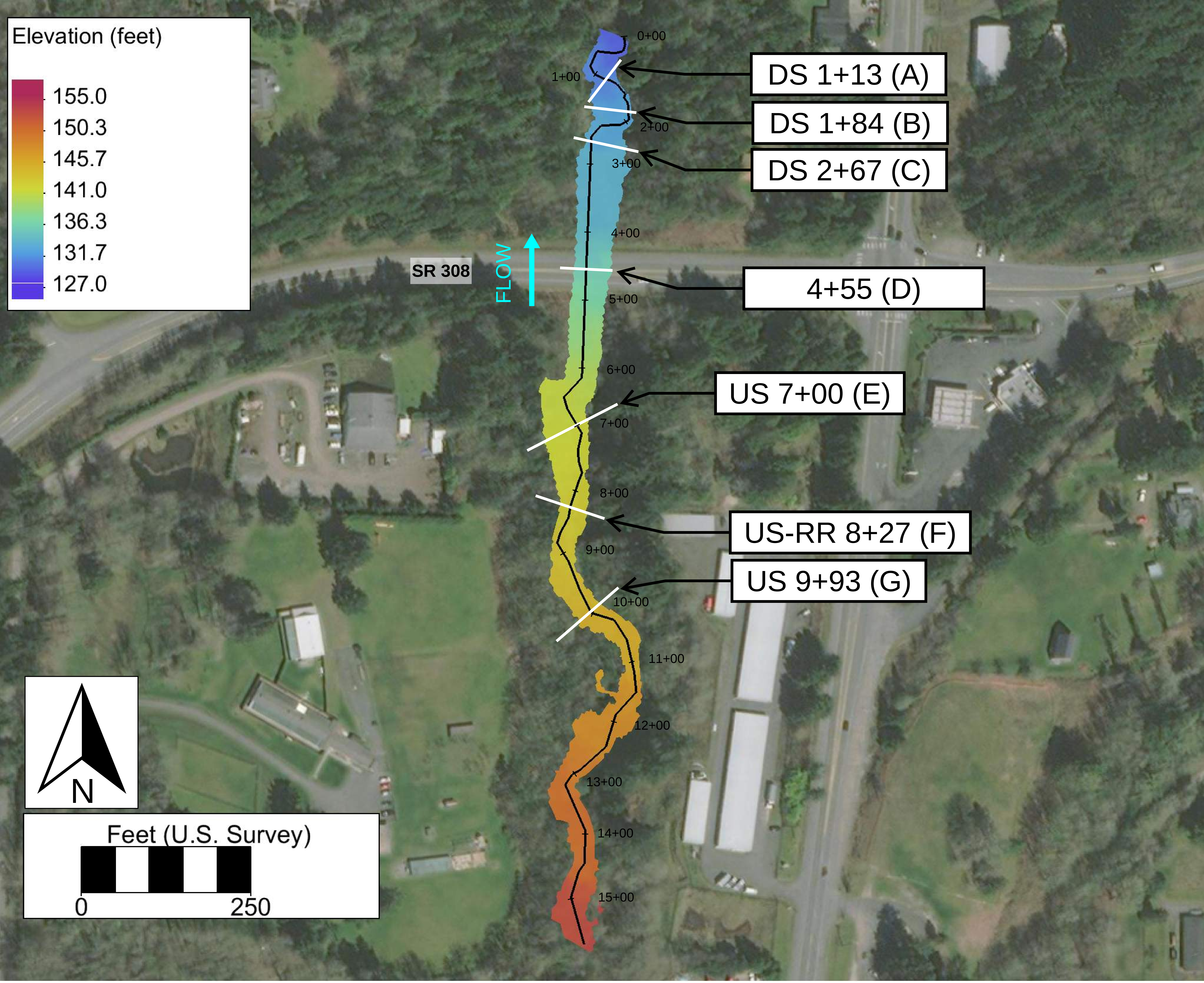


Figure H.24: Natural conditions 500-year water surface elevation

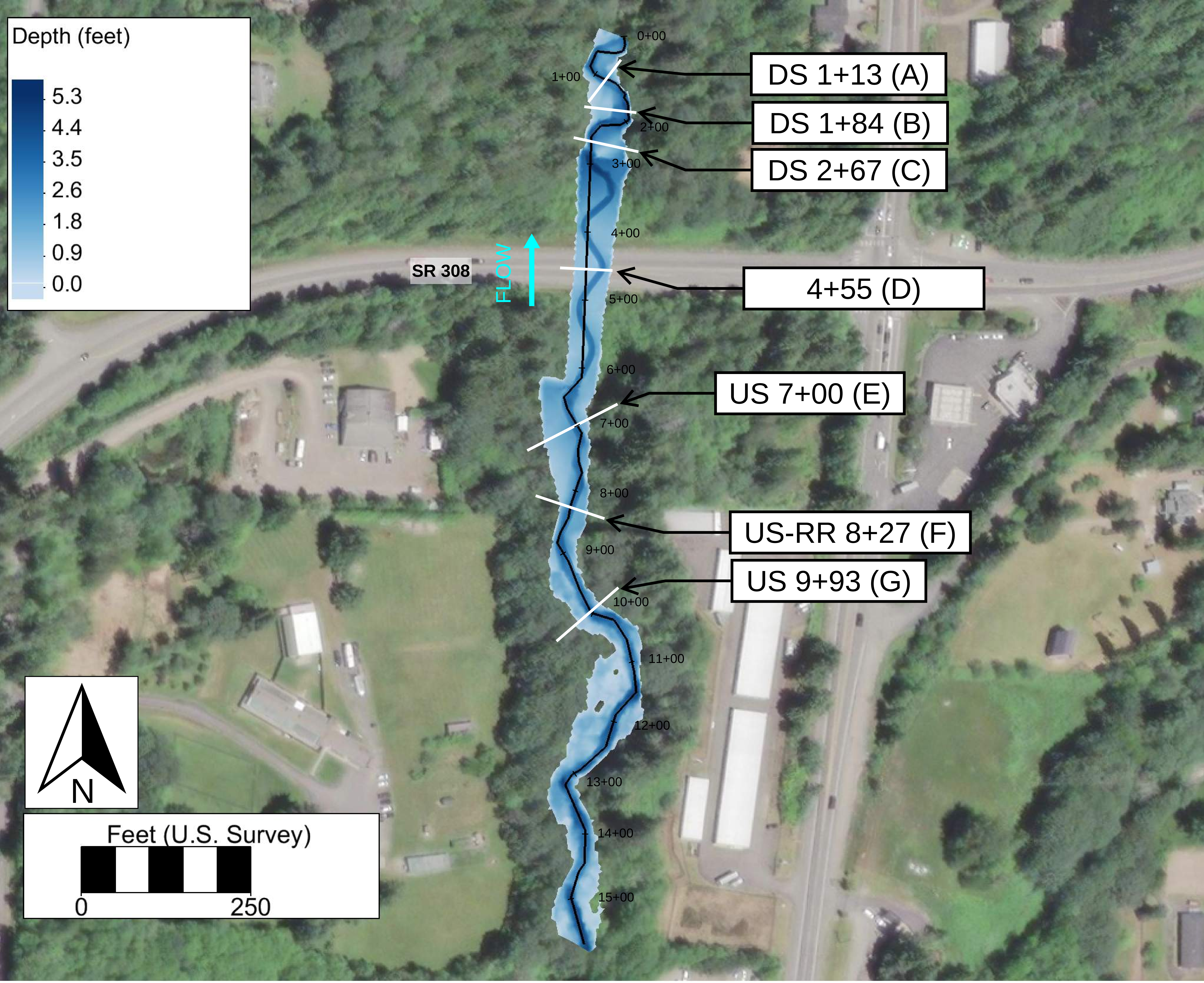


Figure H.25: Natural conditions 2080 100-year depth

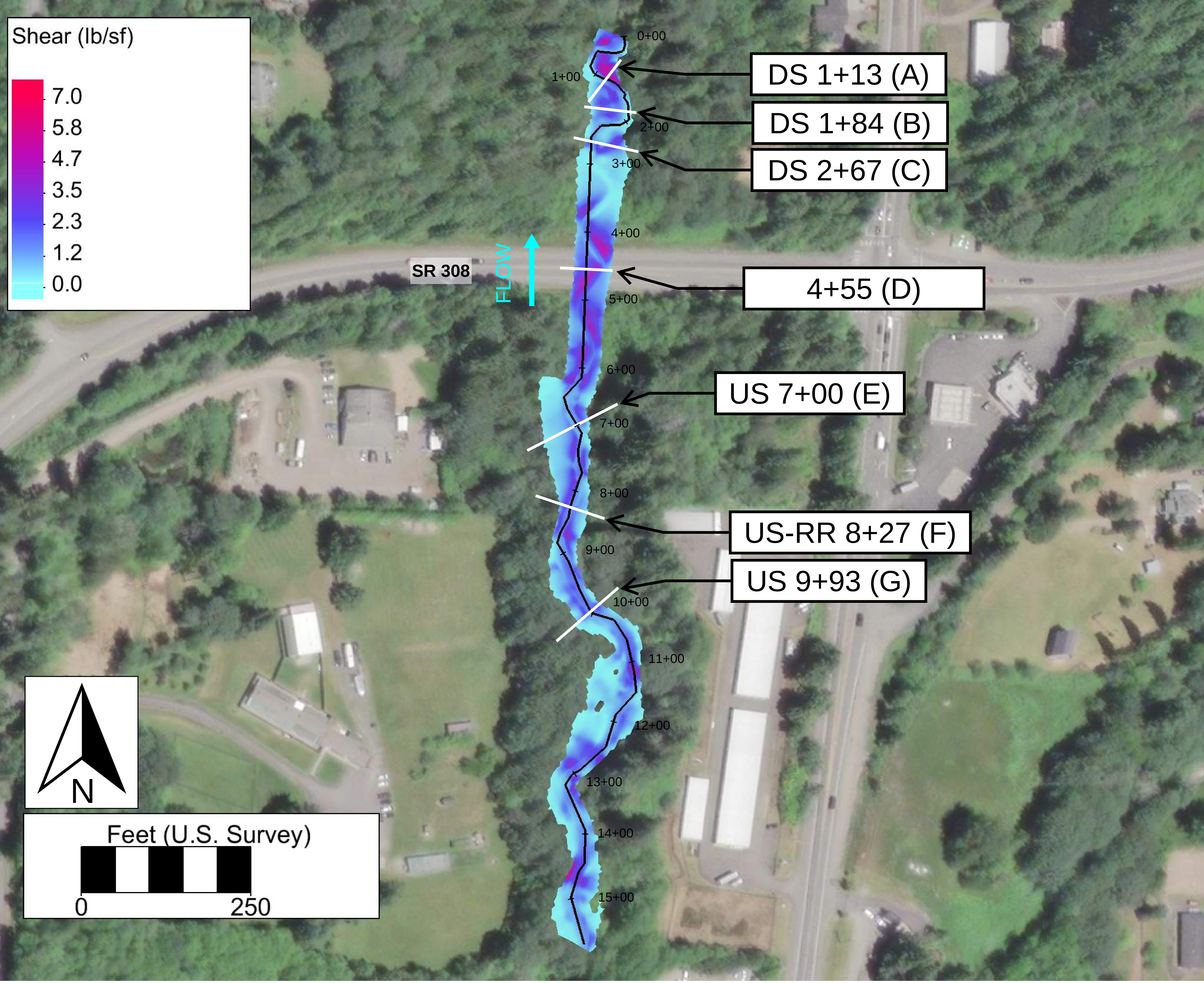


Figure H.26: Natural conditions 2080 100-year shear stress

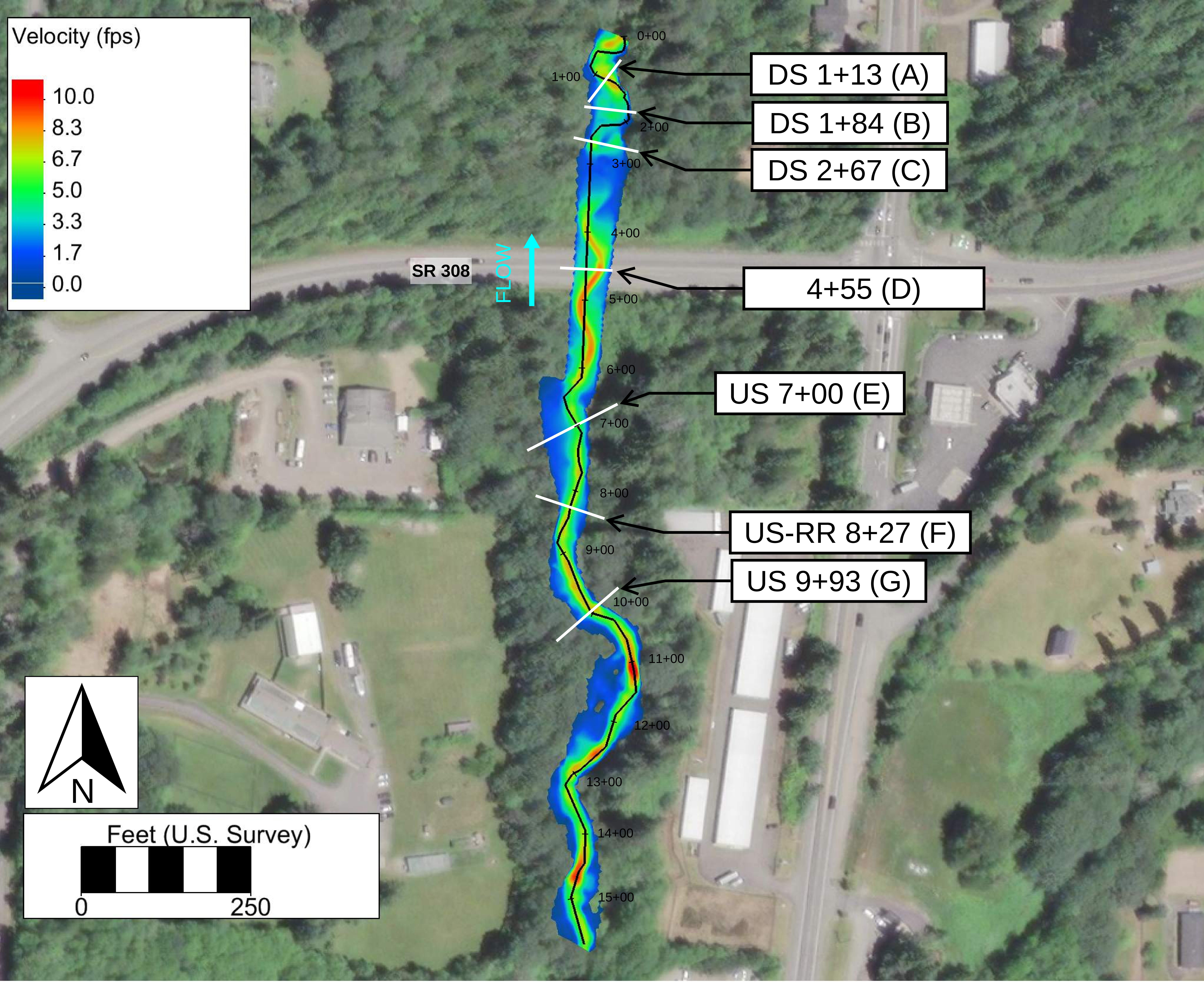


Figure H.27: Natural conditions 2080 100-year velocity

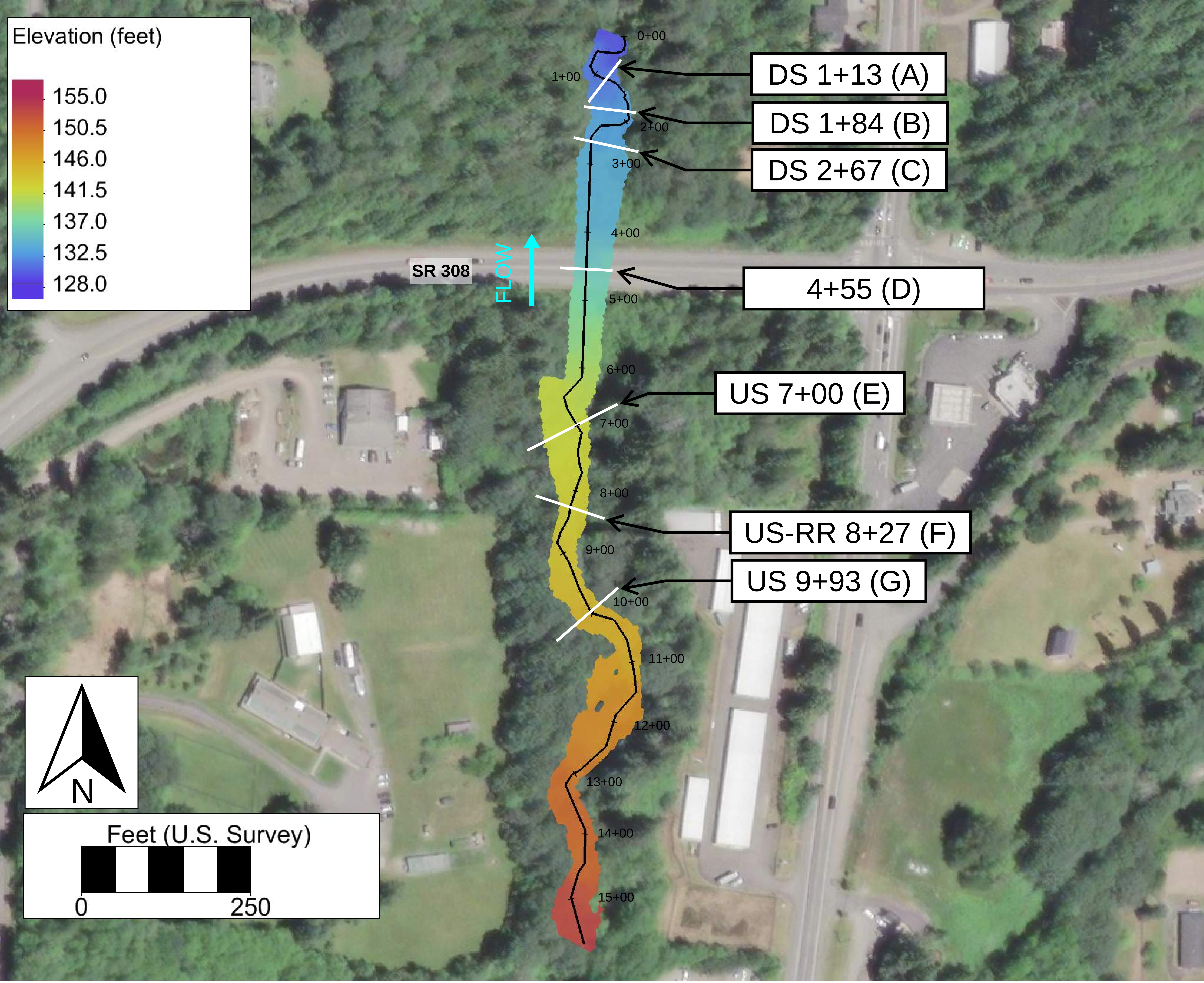


Figure H.28: Natural conditions 2080 100-year water surface elevation

Proposed Conditions SRH-2D Results

Planview

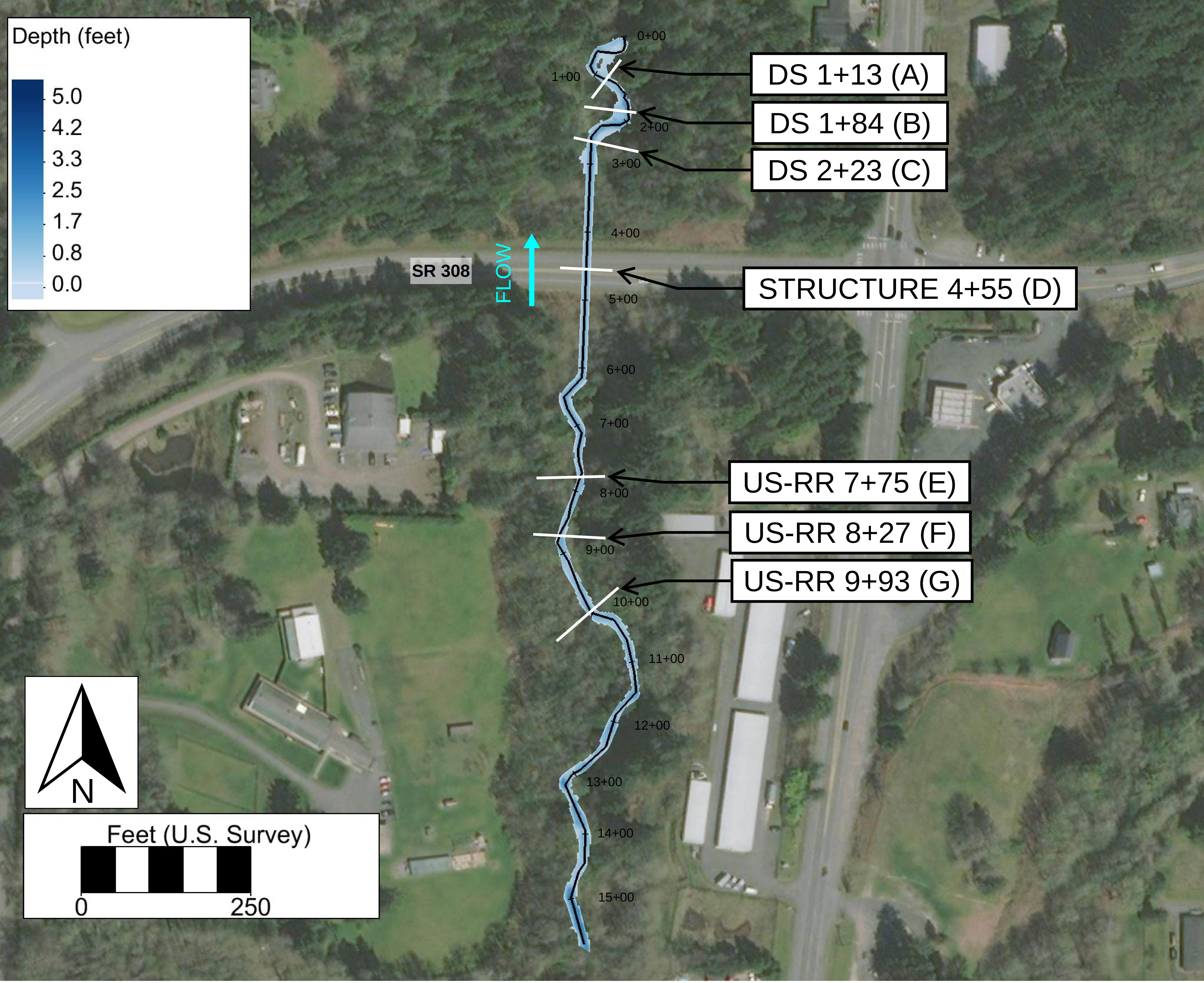


Figure H.29: Proposed conditions 2-year depth

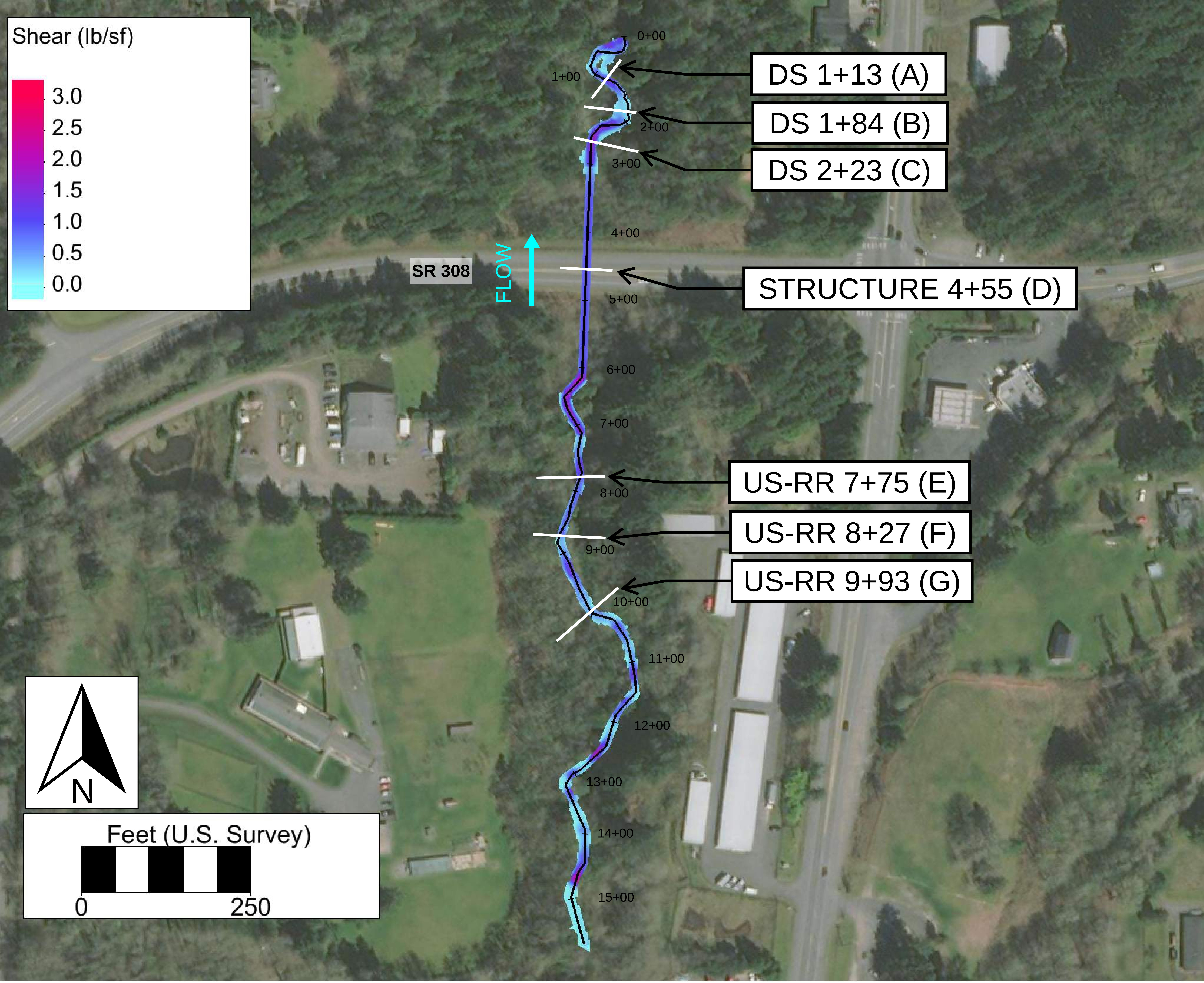


Figure H.30: Proposed conditions 2-year shear stress

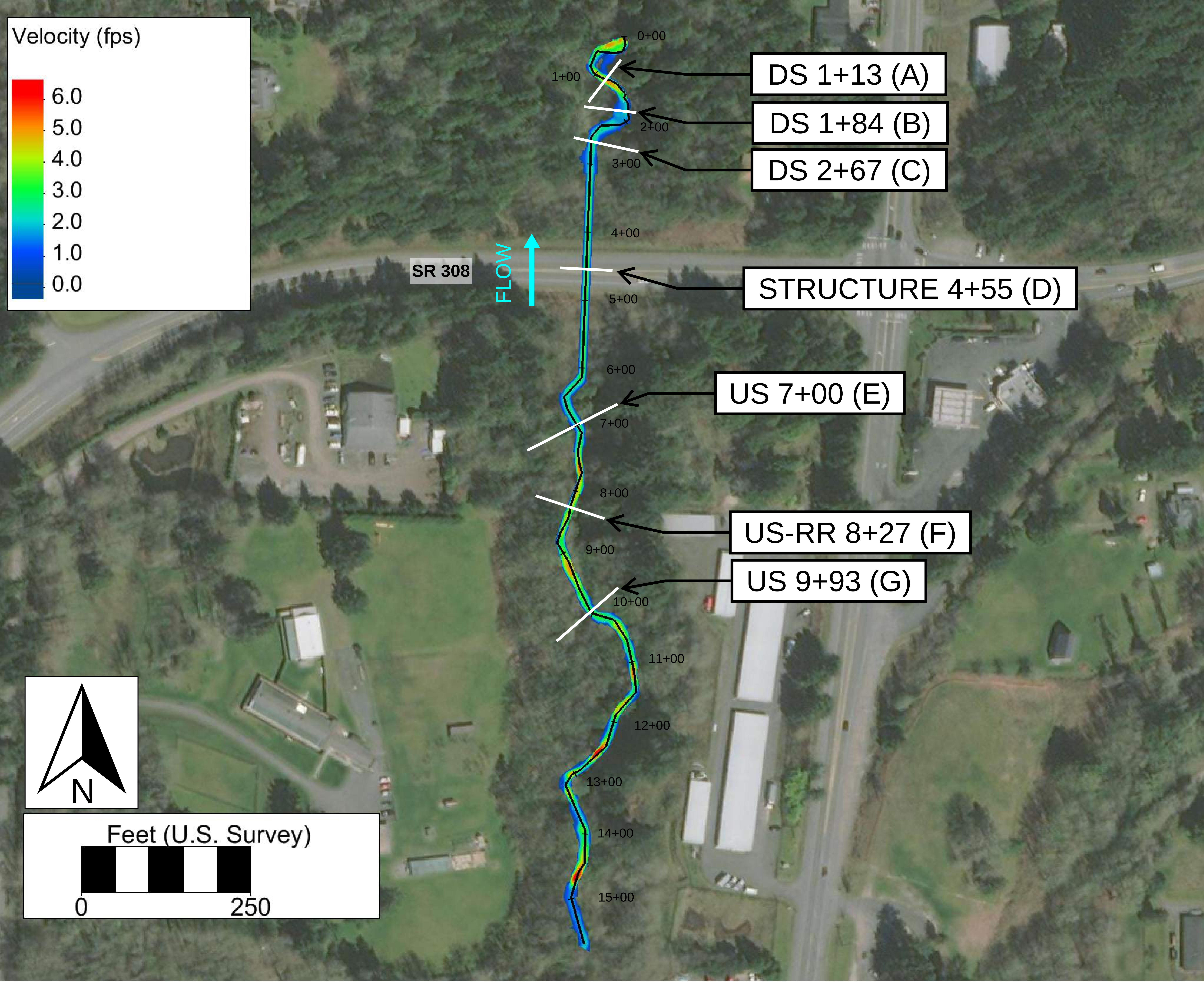


Figure H.31: Proposed conditions 2-year velocity

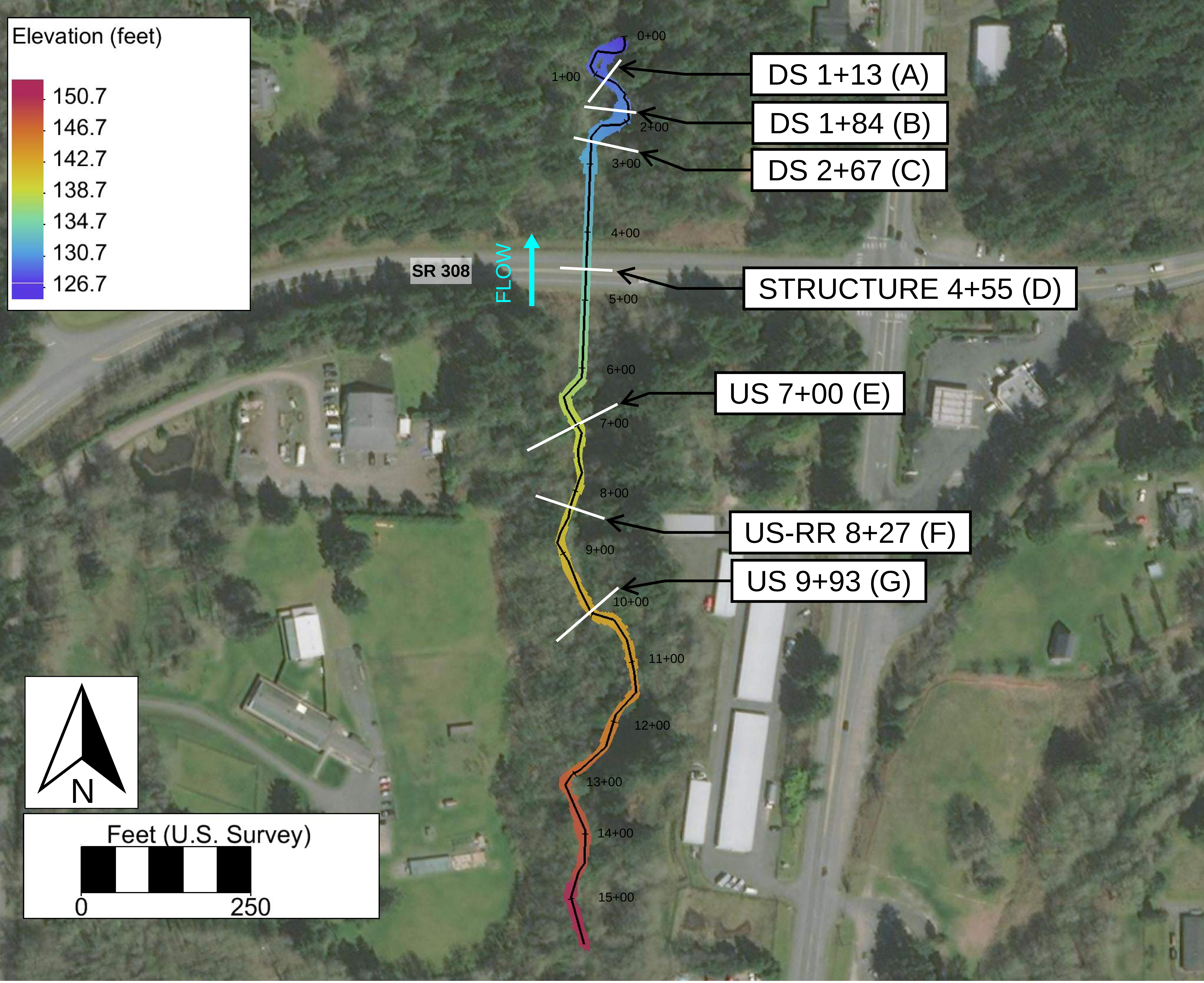


Figure H.32: Proposed conditions 2-year water surface elevation

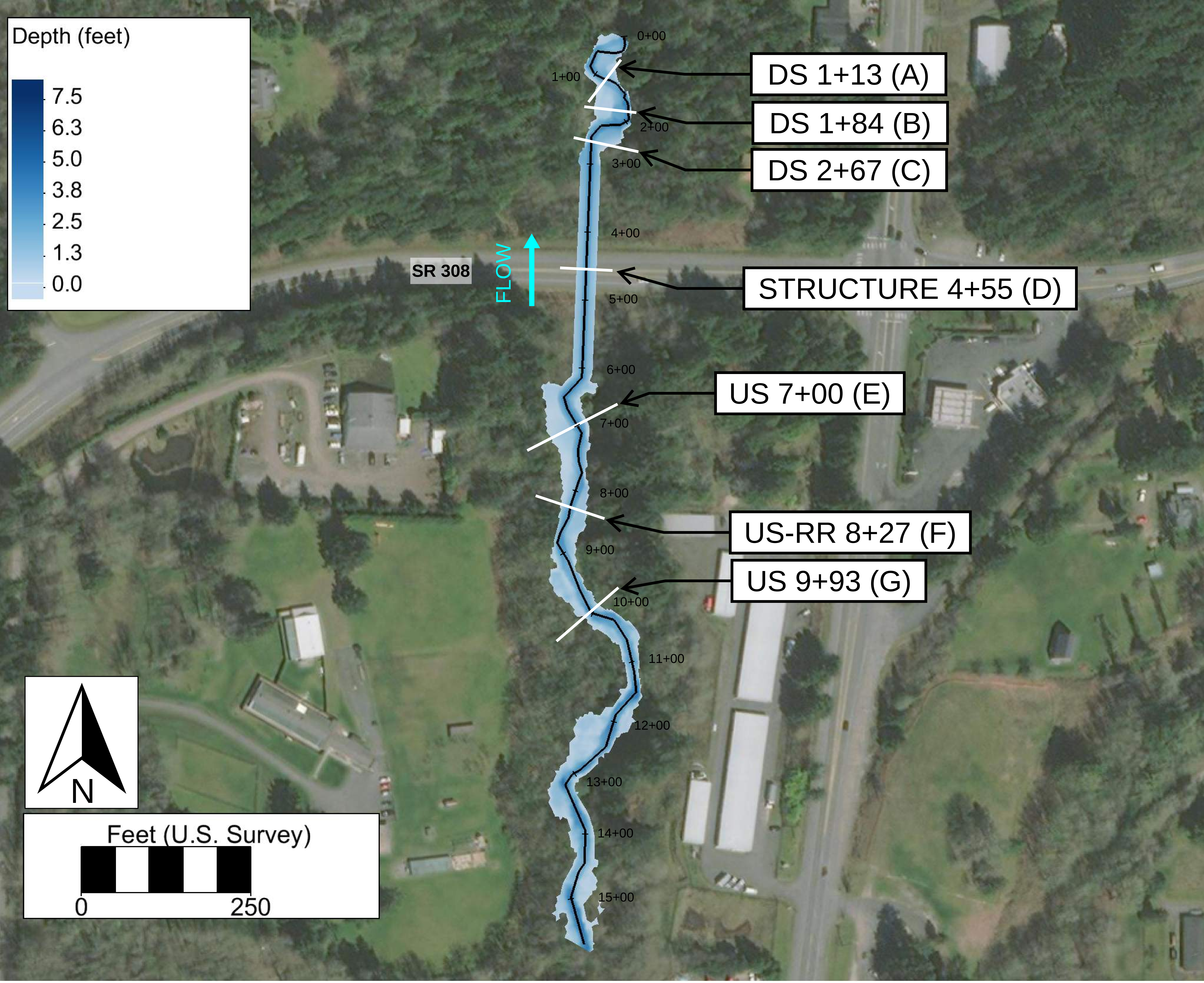


Figure H.33: Proposed conditions 100-year depth

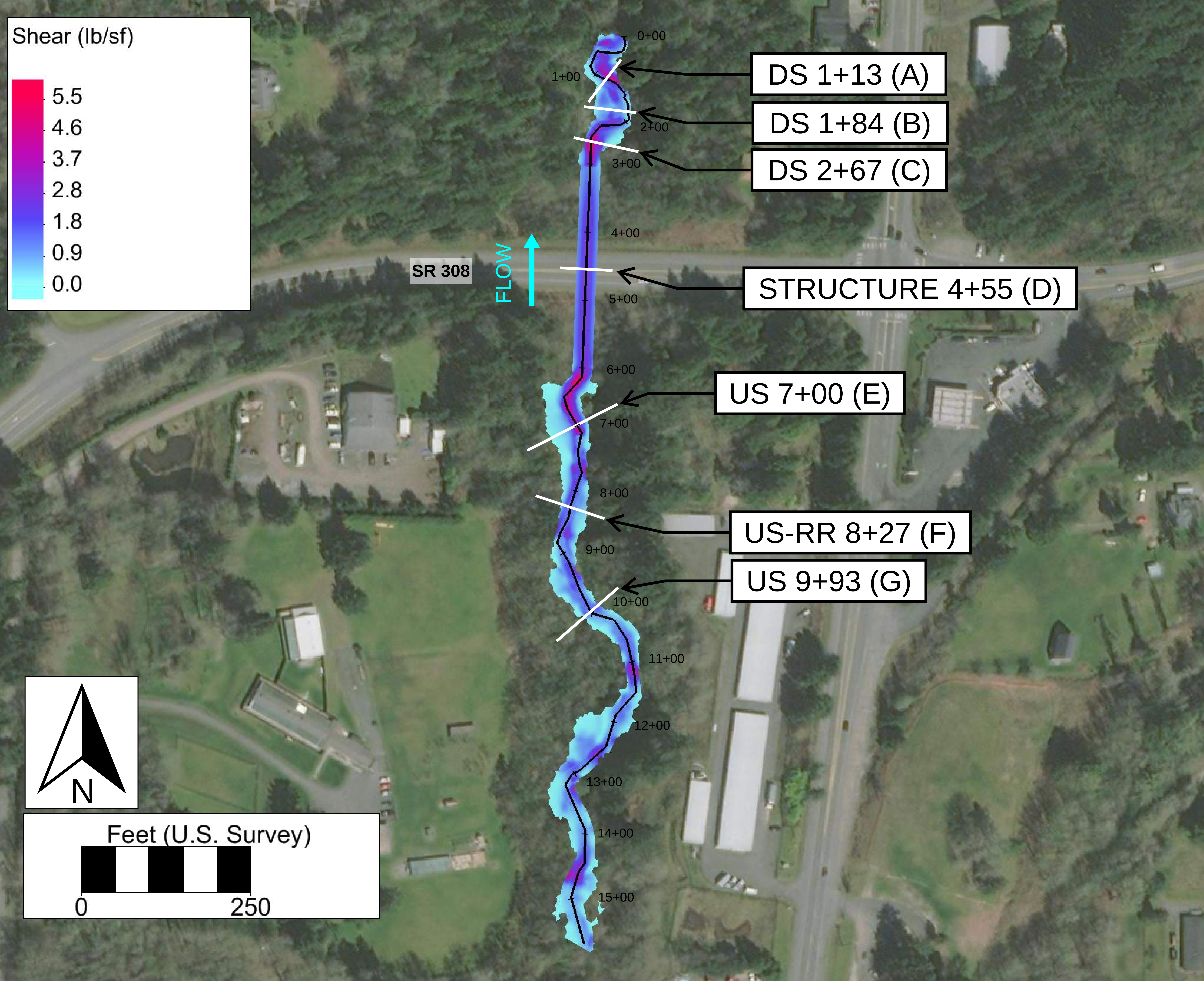


Figure H.34: Proposed conditions 100-year shear stress

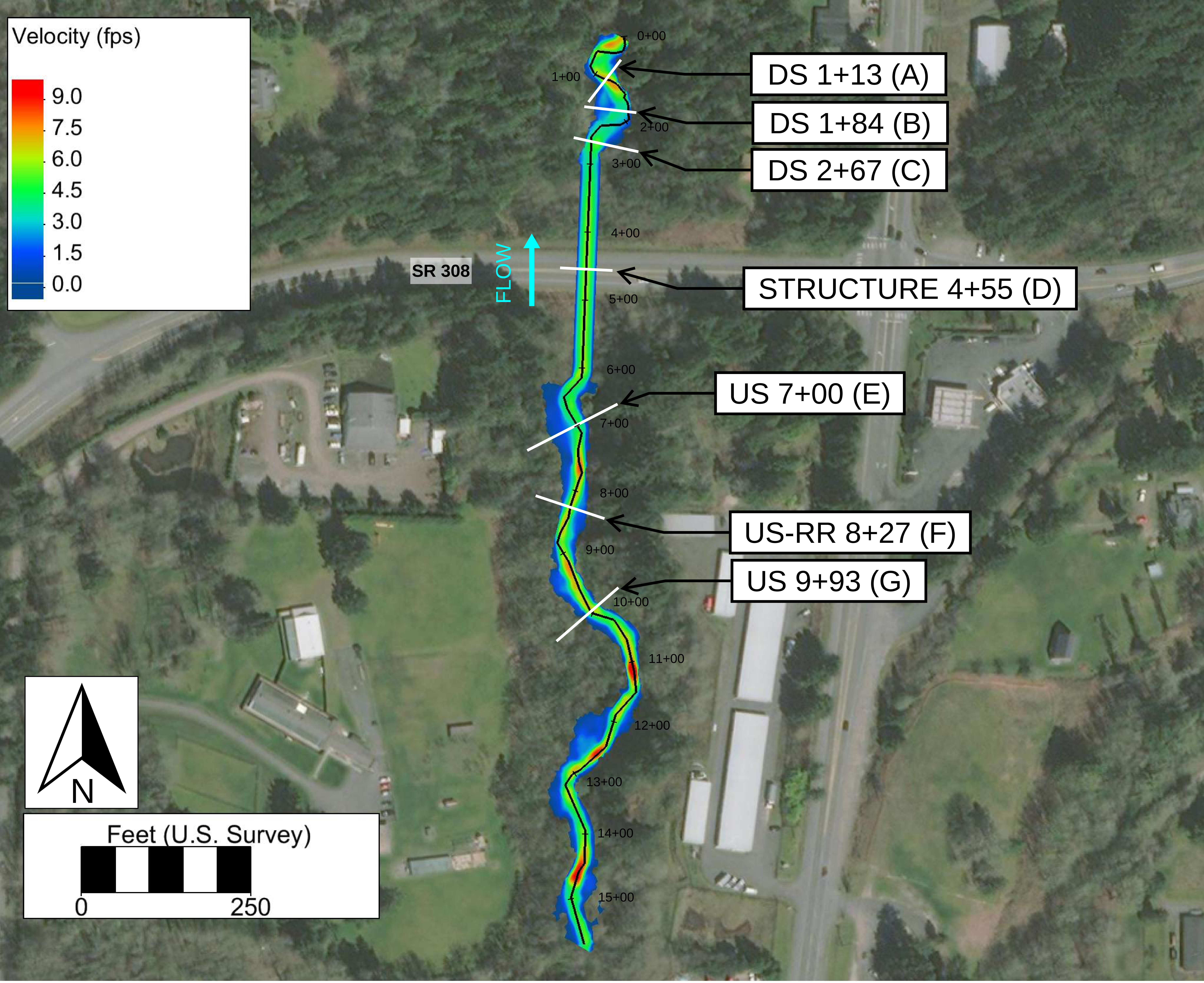


Figure H.35: Proposed conditions 100-year velocity

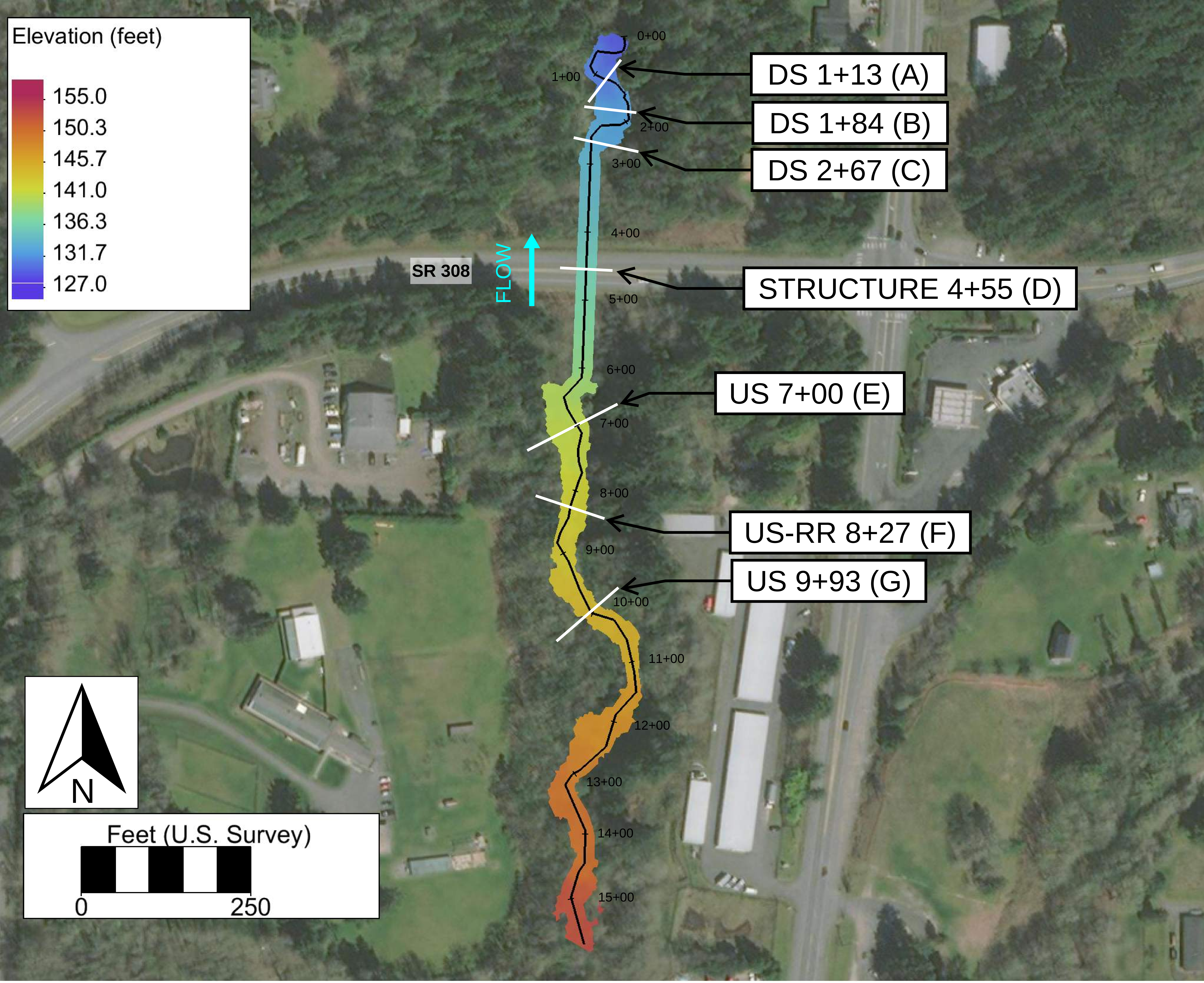


Figure H.36: Proposed conditions 100-year water surface elevation

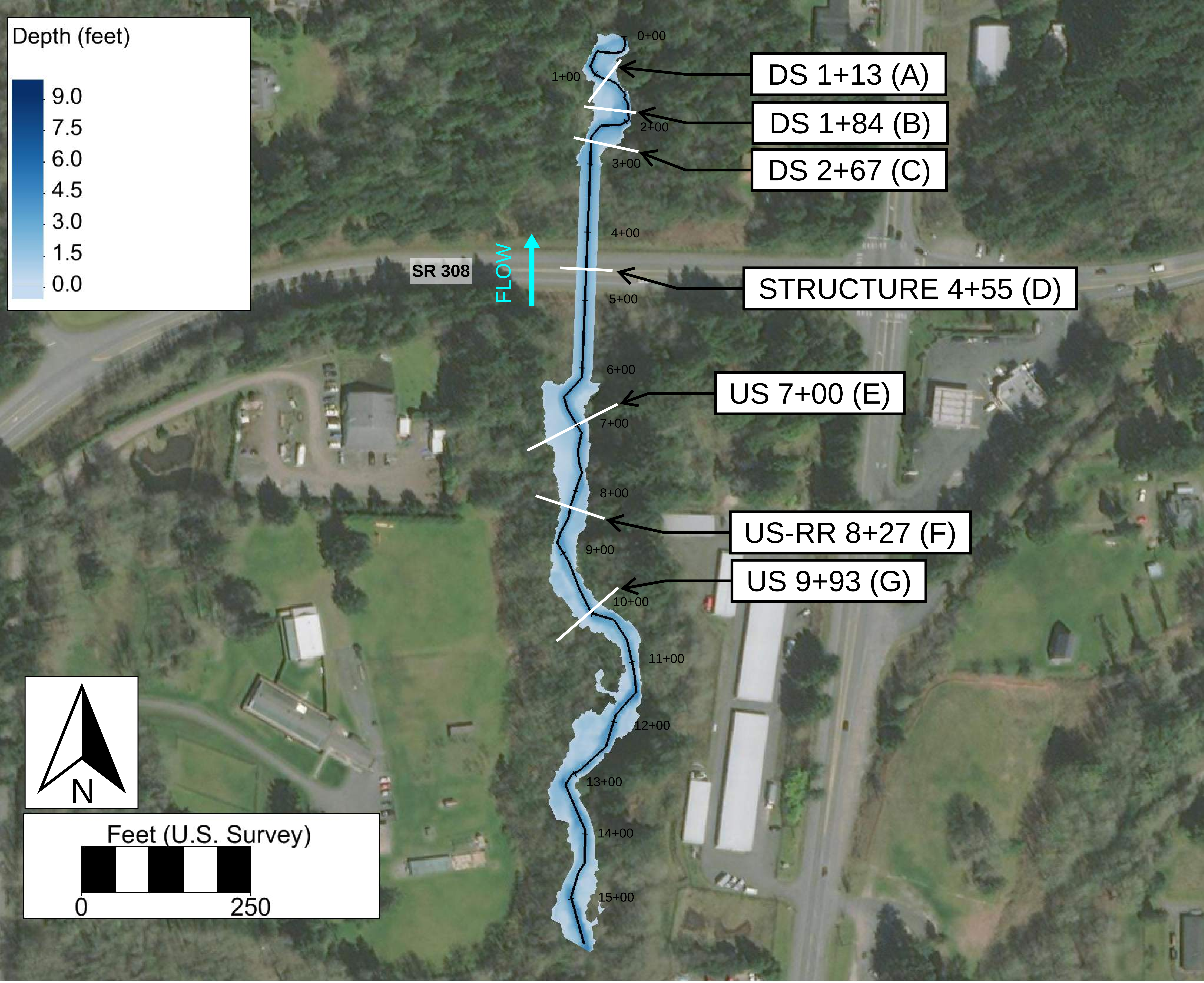


Figure H.37: Proposed conditions 500-year depth

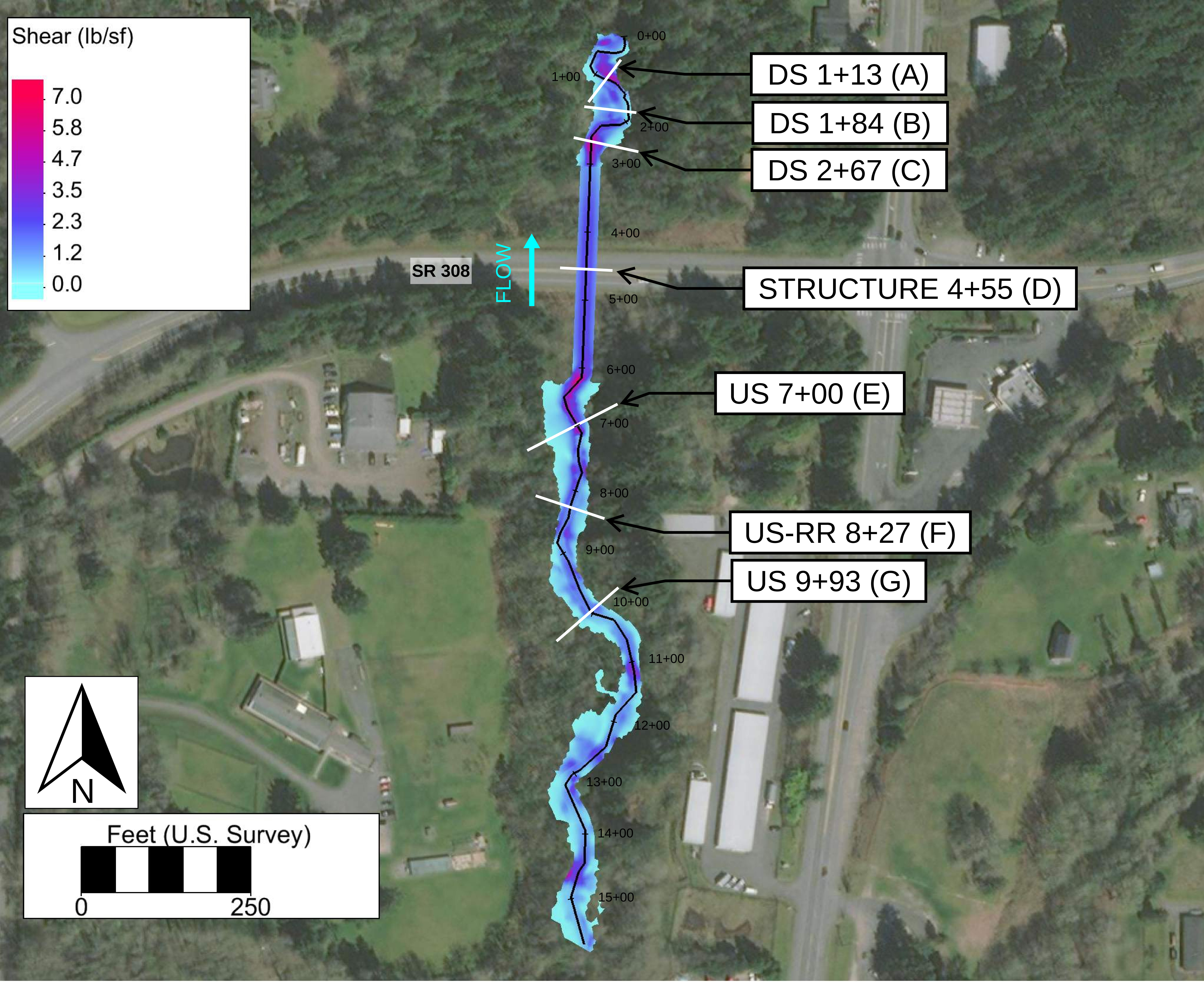


Figure H.38: Proposed conditions 500-year shear stress

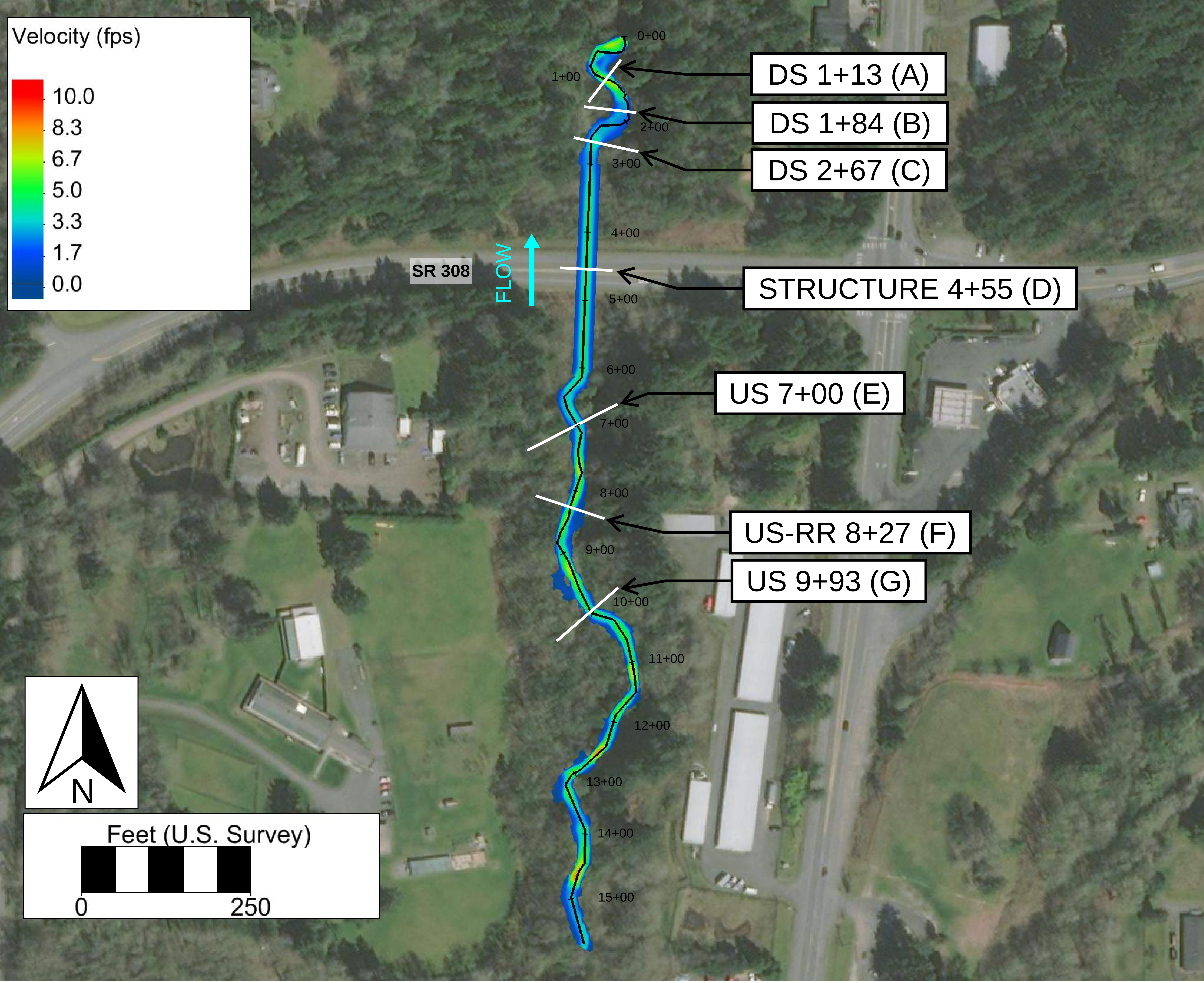


Figure H.39: Proposed conditions 500-year velocity

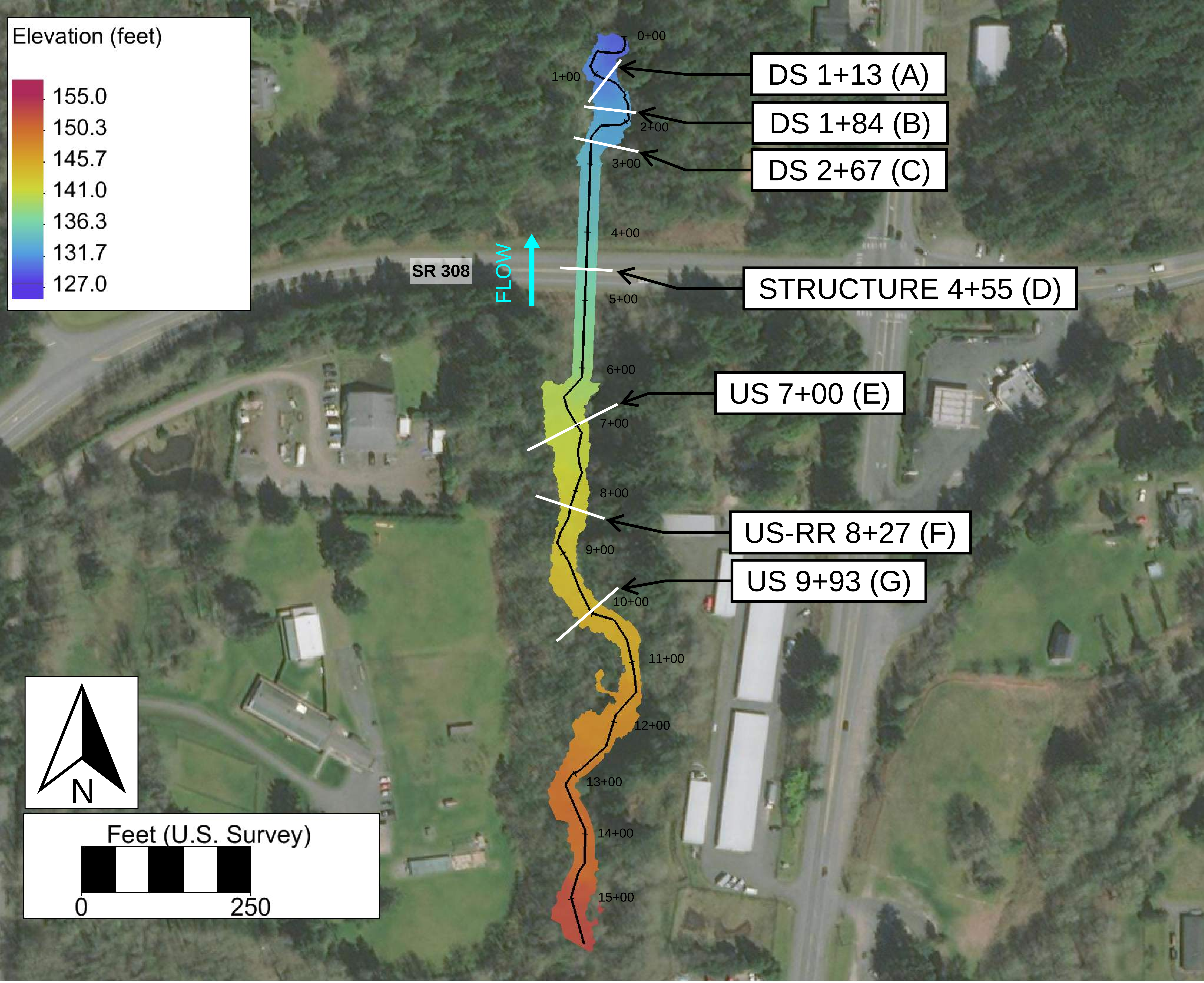


Figure H.40: Proposed conditions 500-year water surface elevation

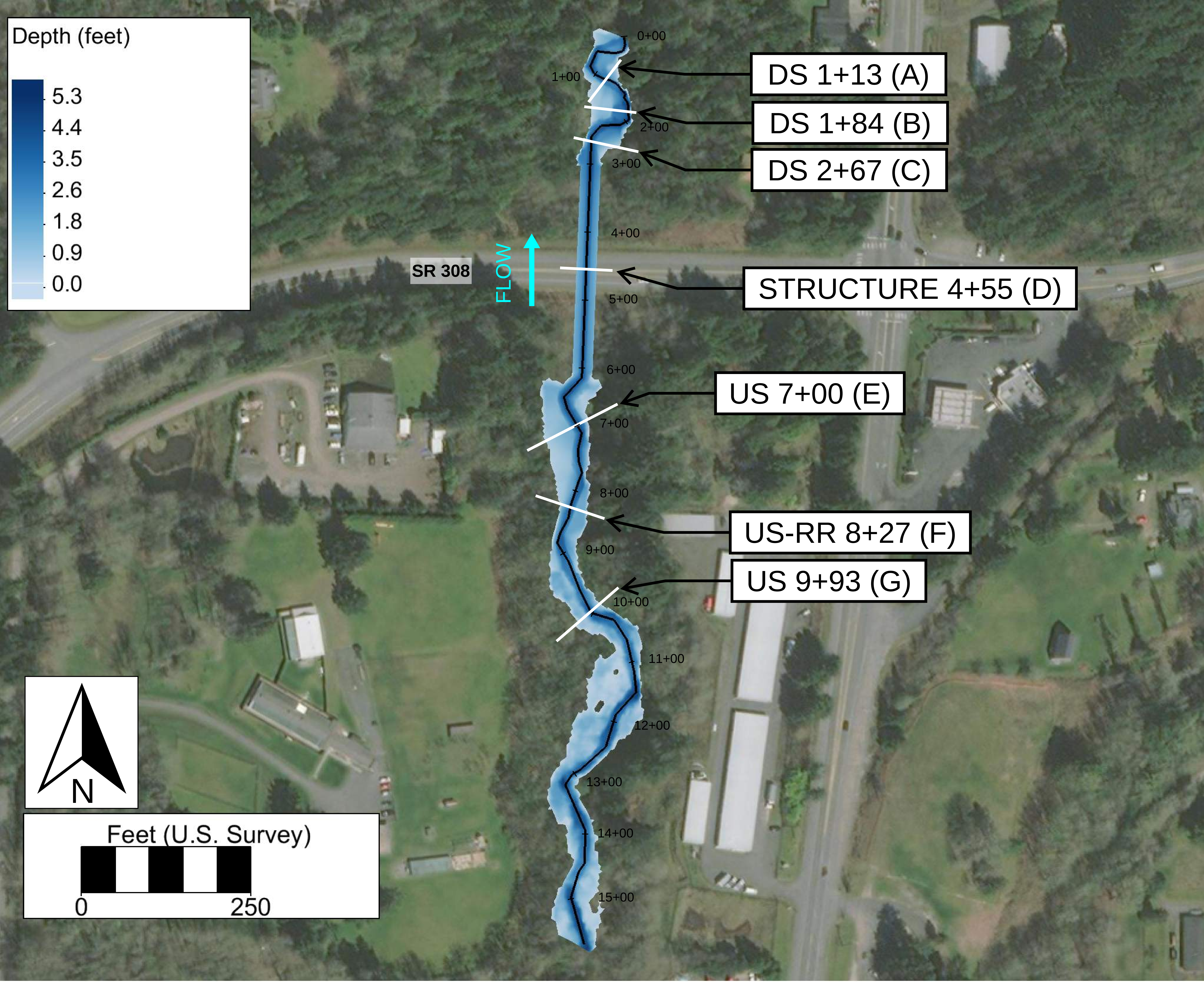


Figure H.41: Proposed conditions 2080 100-year depth

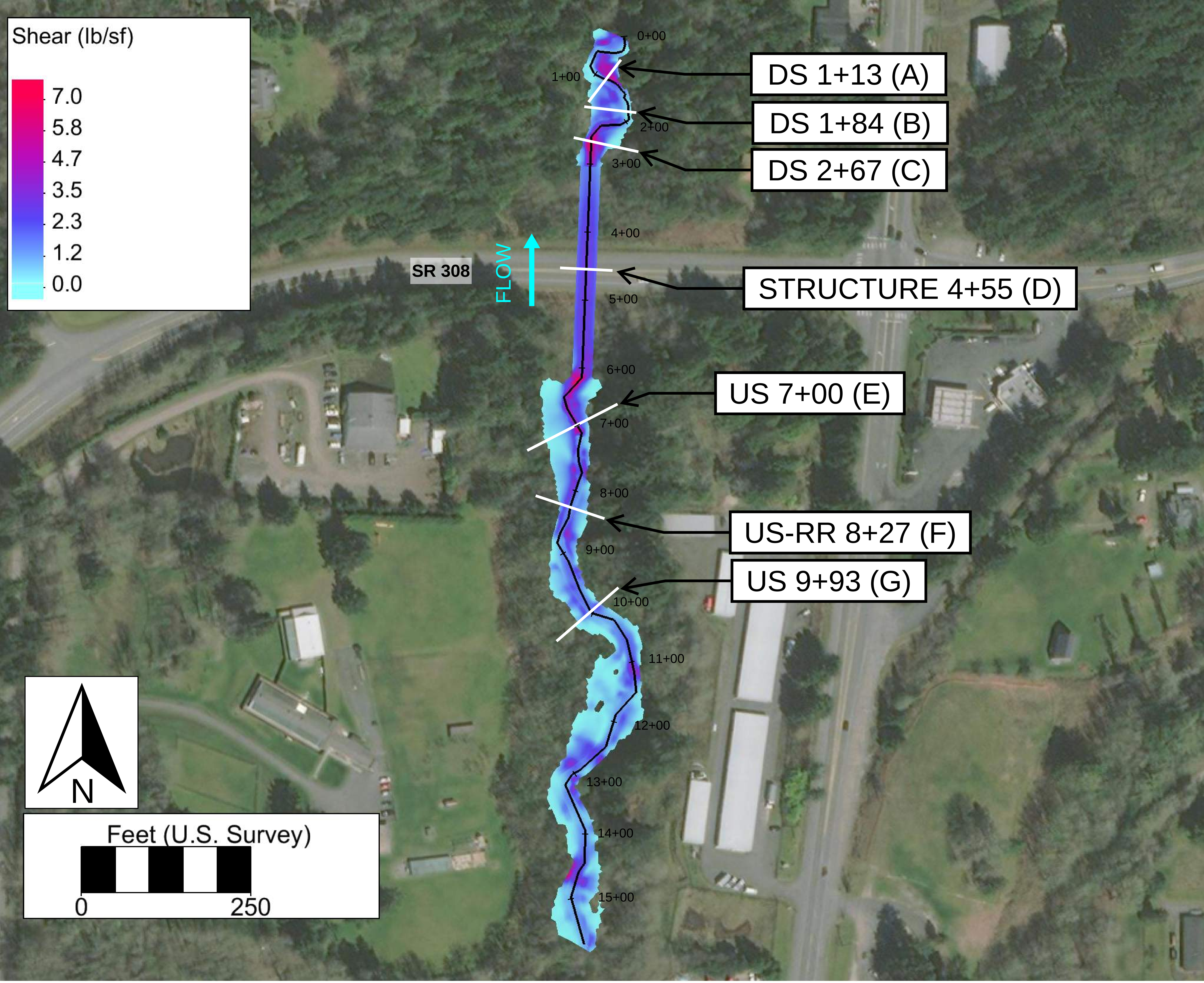


Figure H.42: Proposed conditions 2080 100-year shear stress

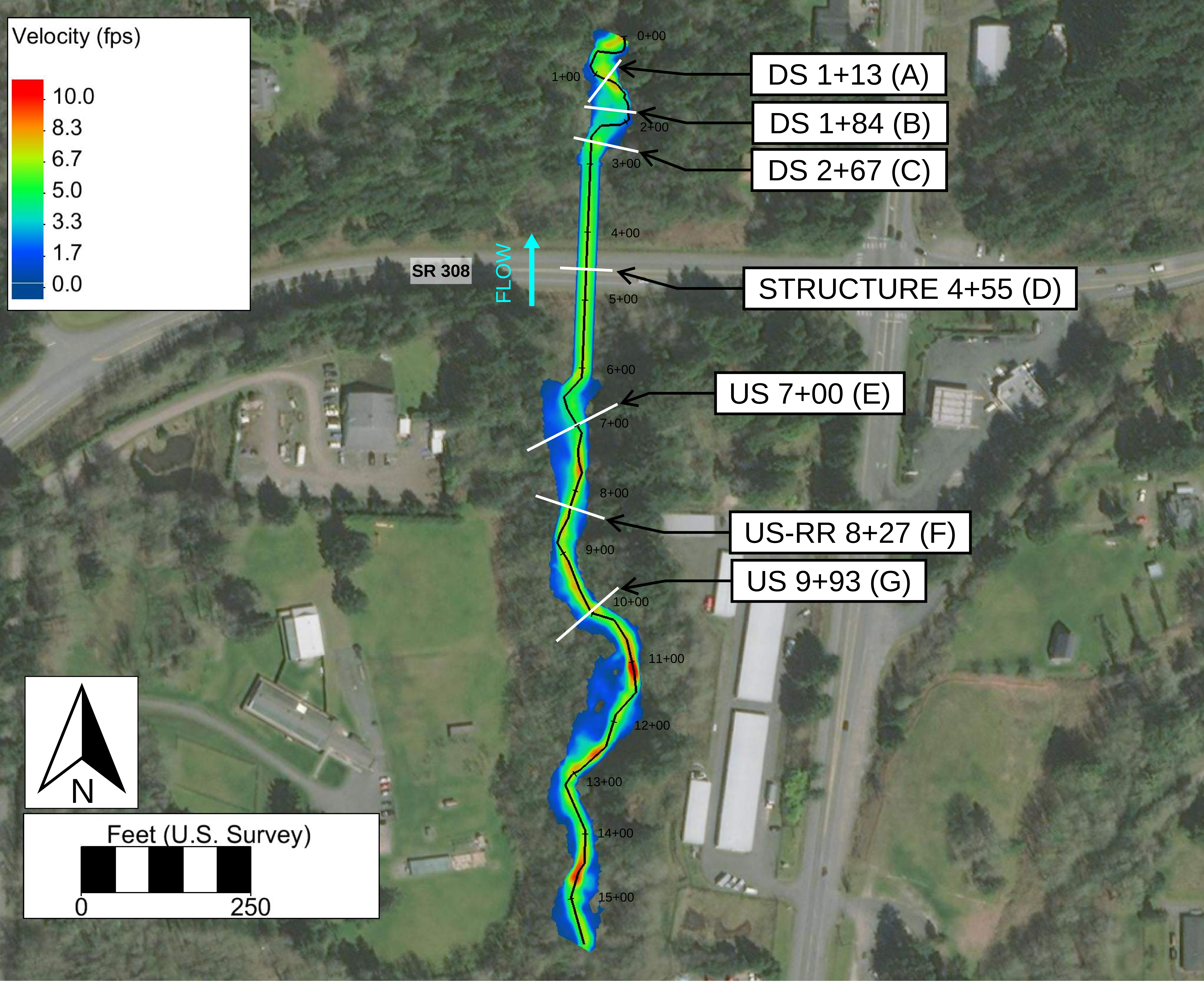


Figure H.43: Proposed conditions 2080 100-year velocity

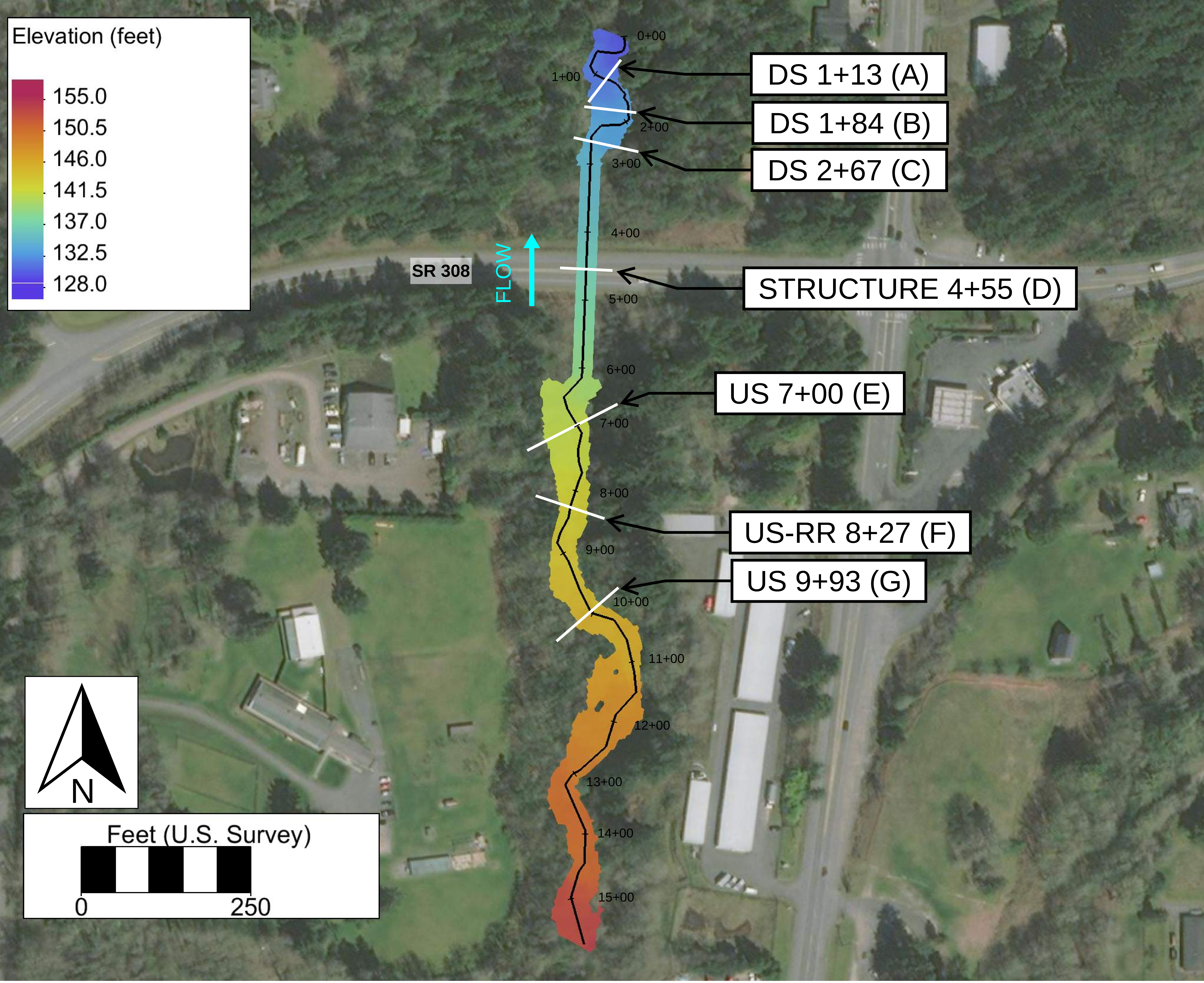


Figure H.44: Proposed conditions 2080 100-year water surface elevation

Existing Conditions SRH-2D Results

Cross Sections

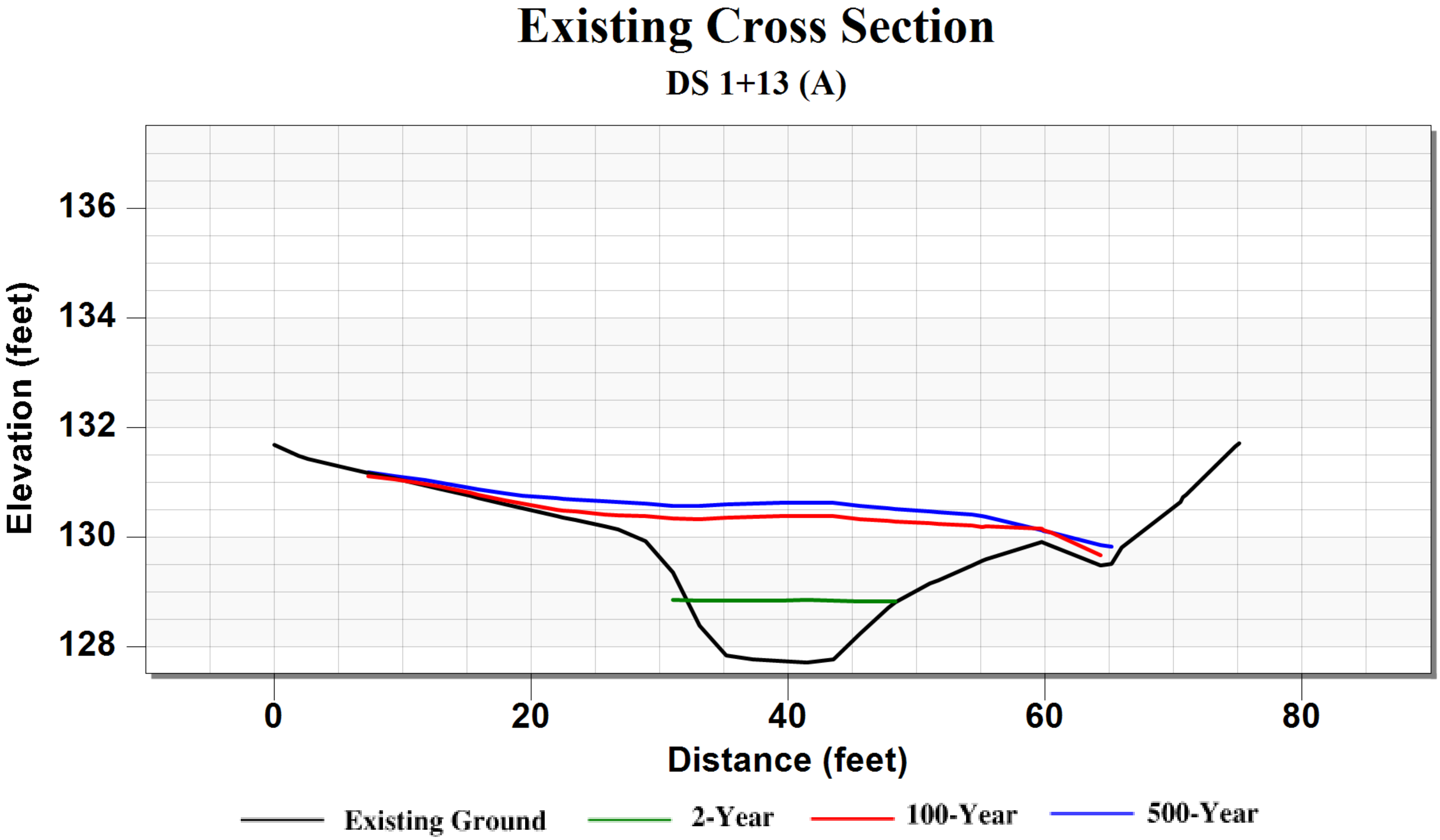


Figure H.45: Existing conditions cross section at downstream station 1+13 (A)

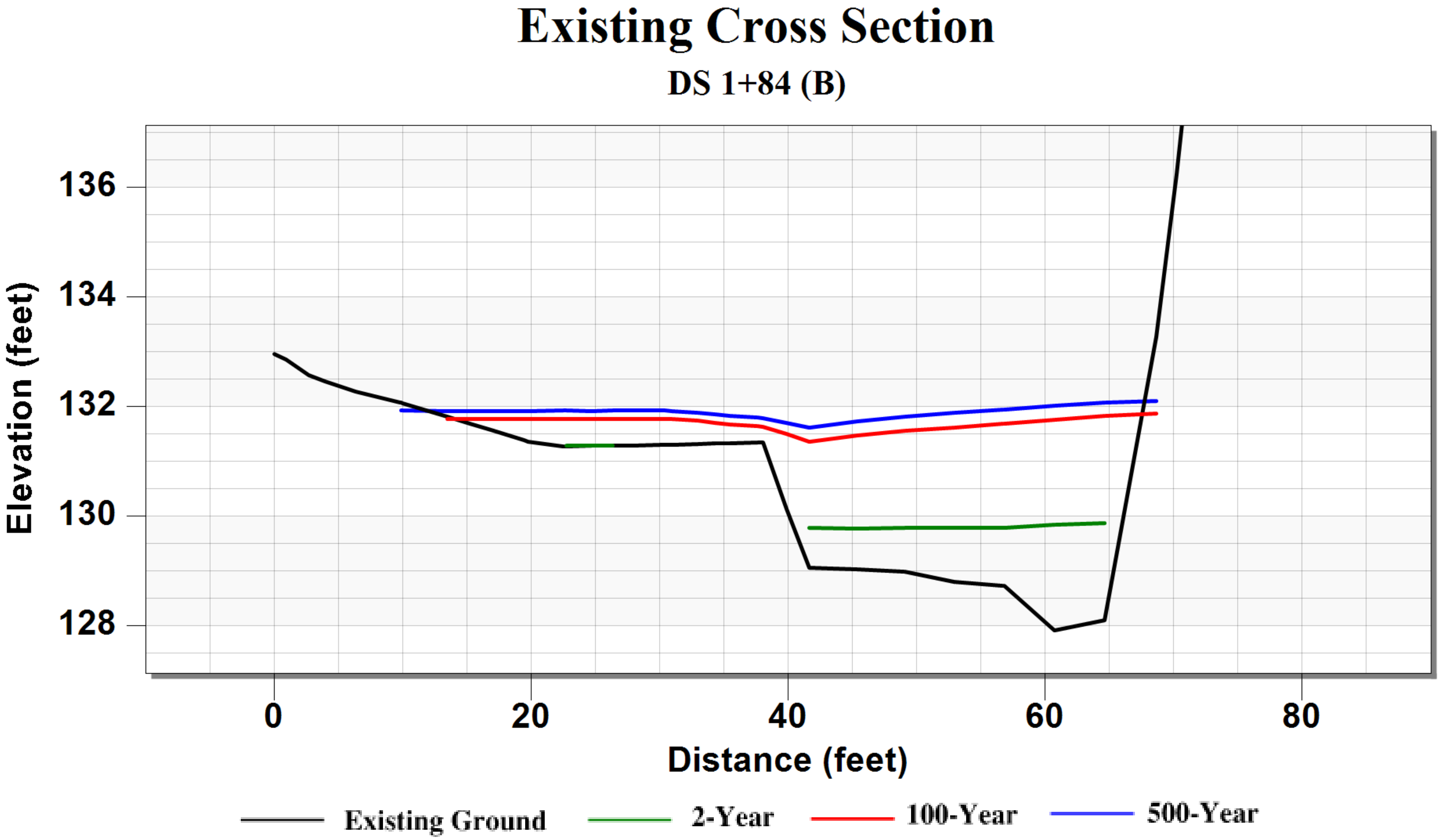


Figure H.46: Existing conditions cross section at downstream station 1+84 (B)

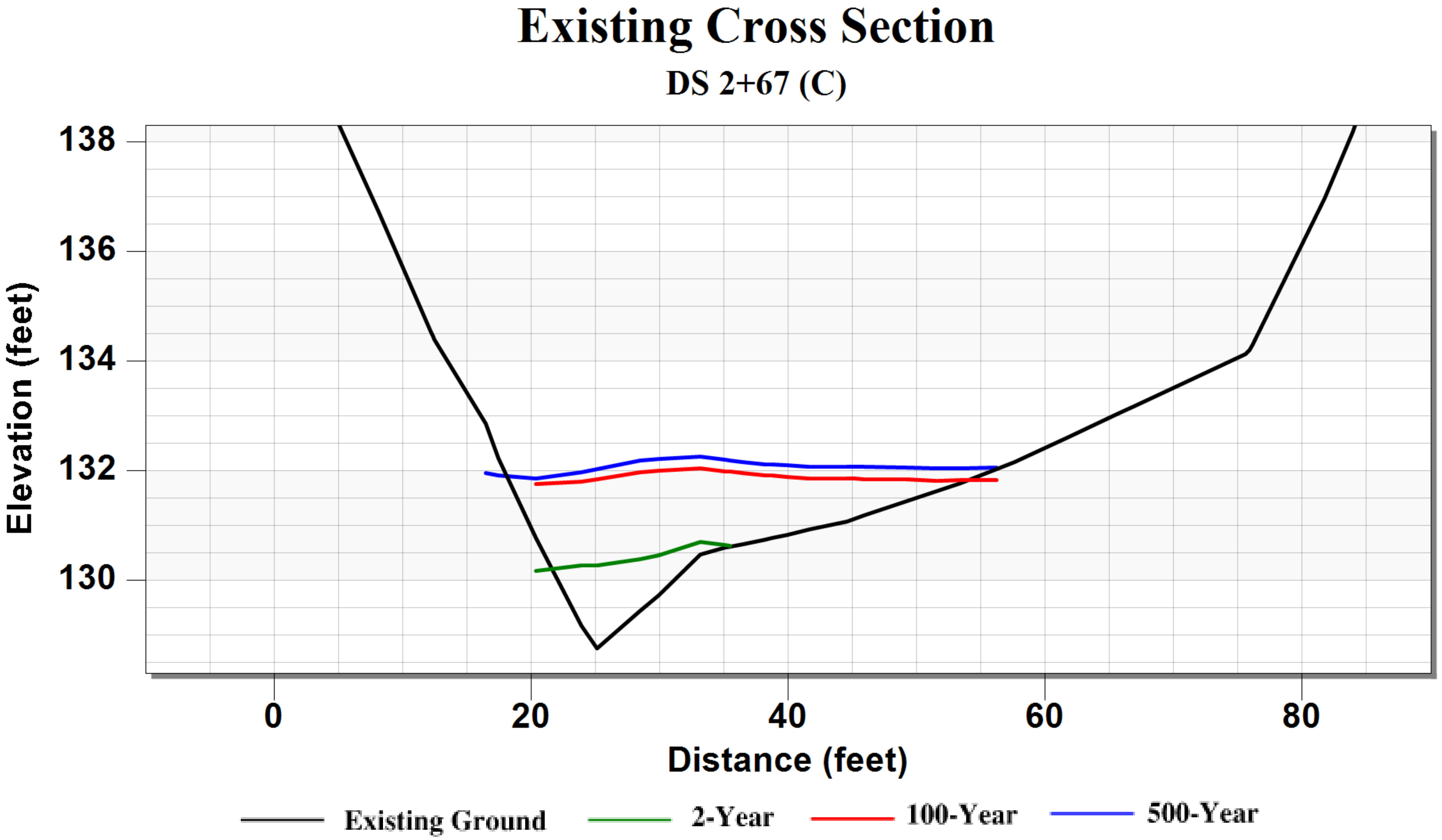


Figure H.47: Existing conditions cross section at downstream station 2+67 (C)

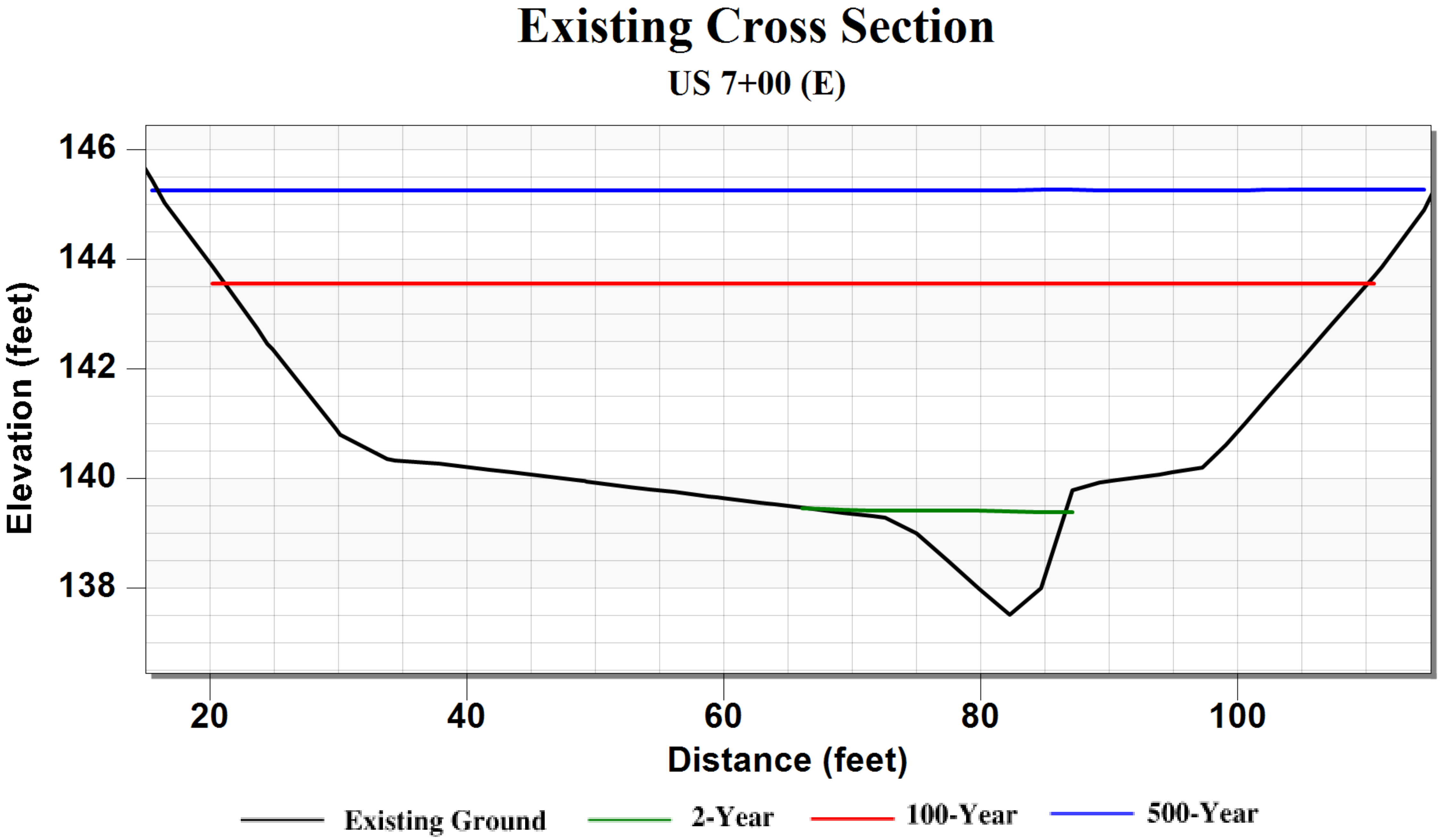


Figure H.48: Existing conditions cross section at upstream station 7+00 (E)

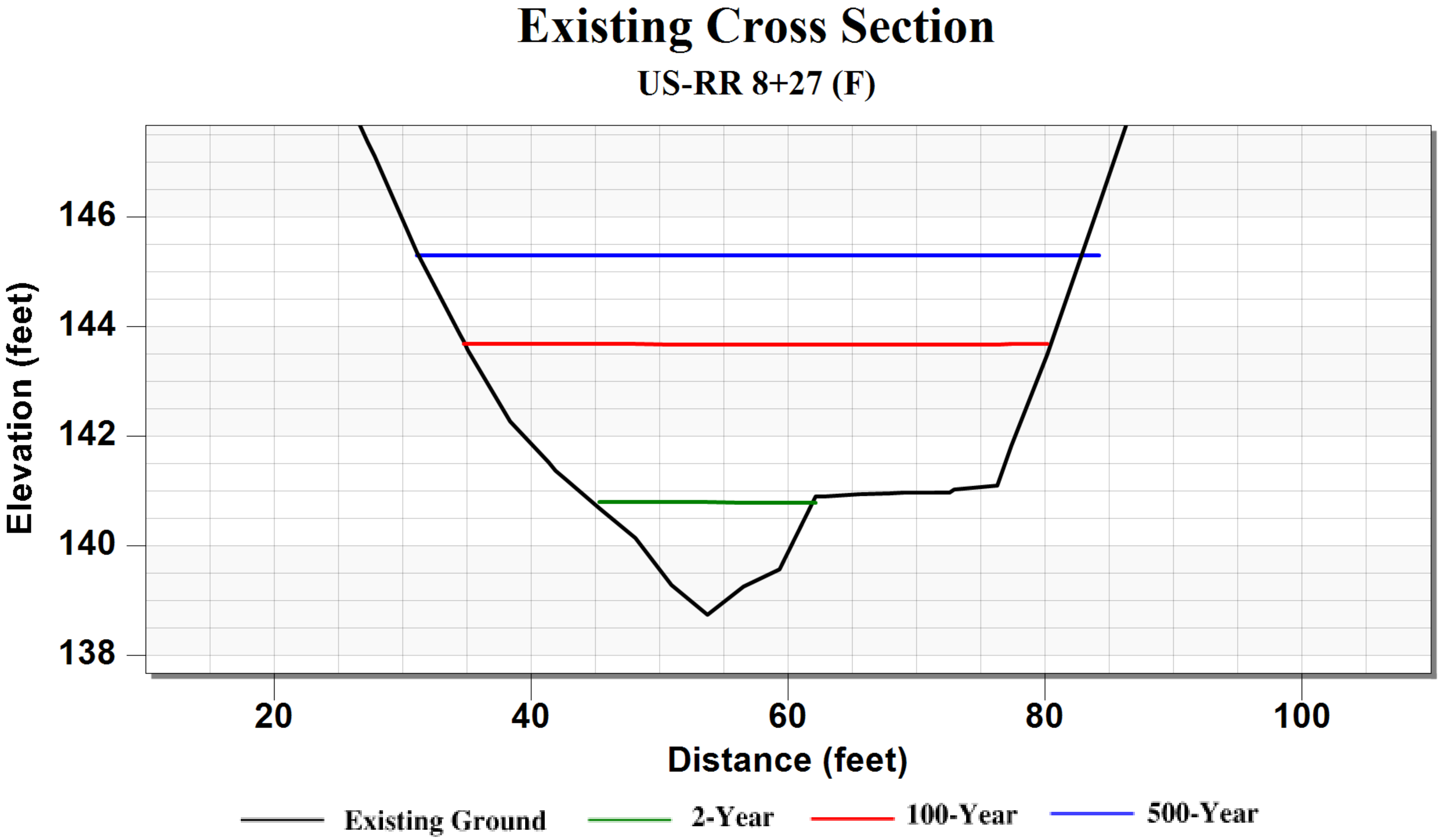


Figure H.49: Existing conditions cross section at upstream station US-RR 8+27 (F)

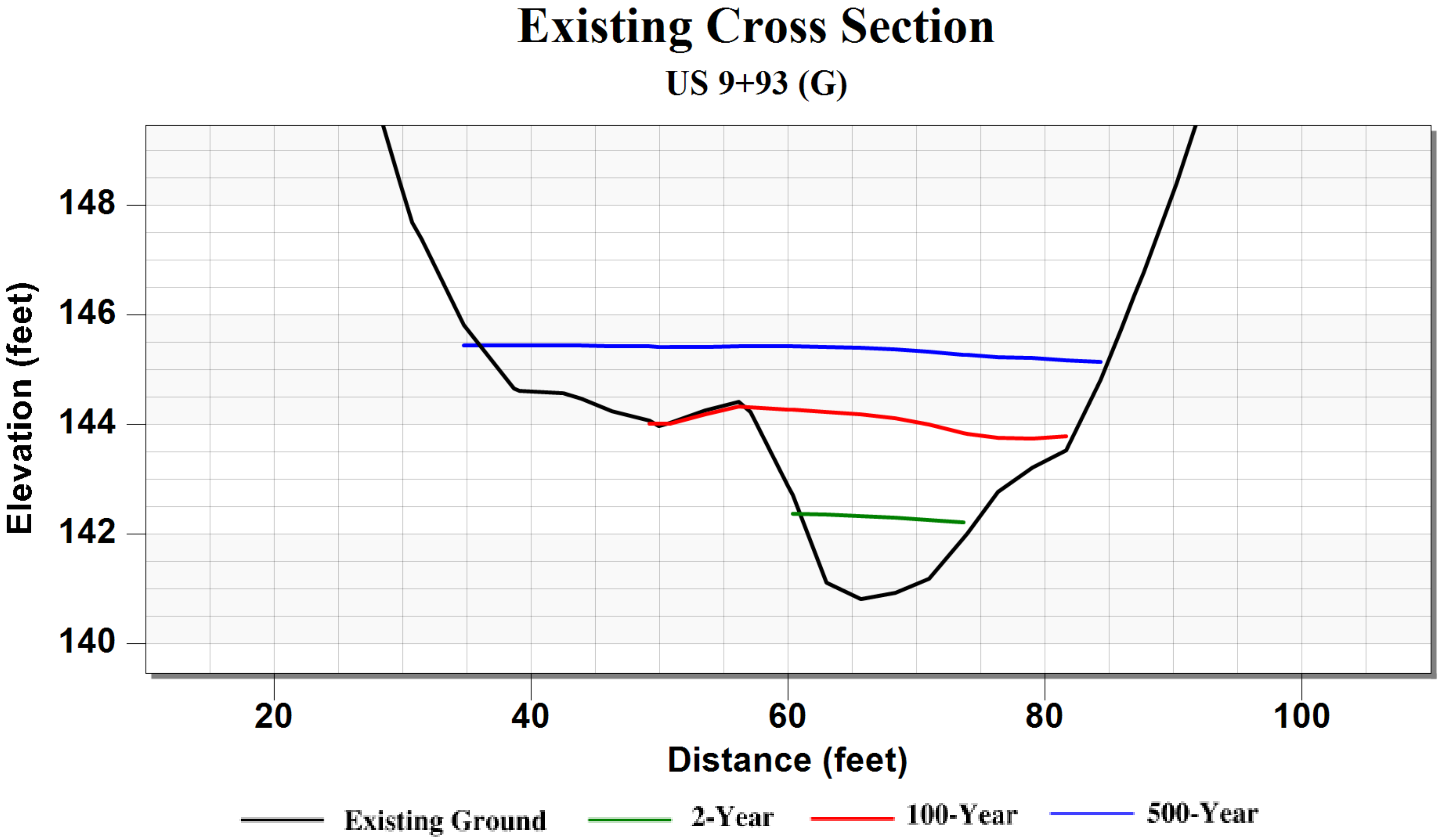


Figure H.50: Existing conditions cross section at upstream station 9+93 (G)

Natural Conditions SRH-2D Results

Cross Sections

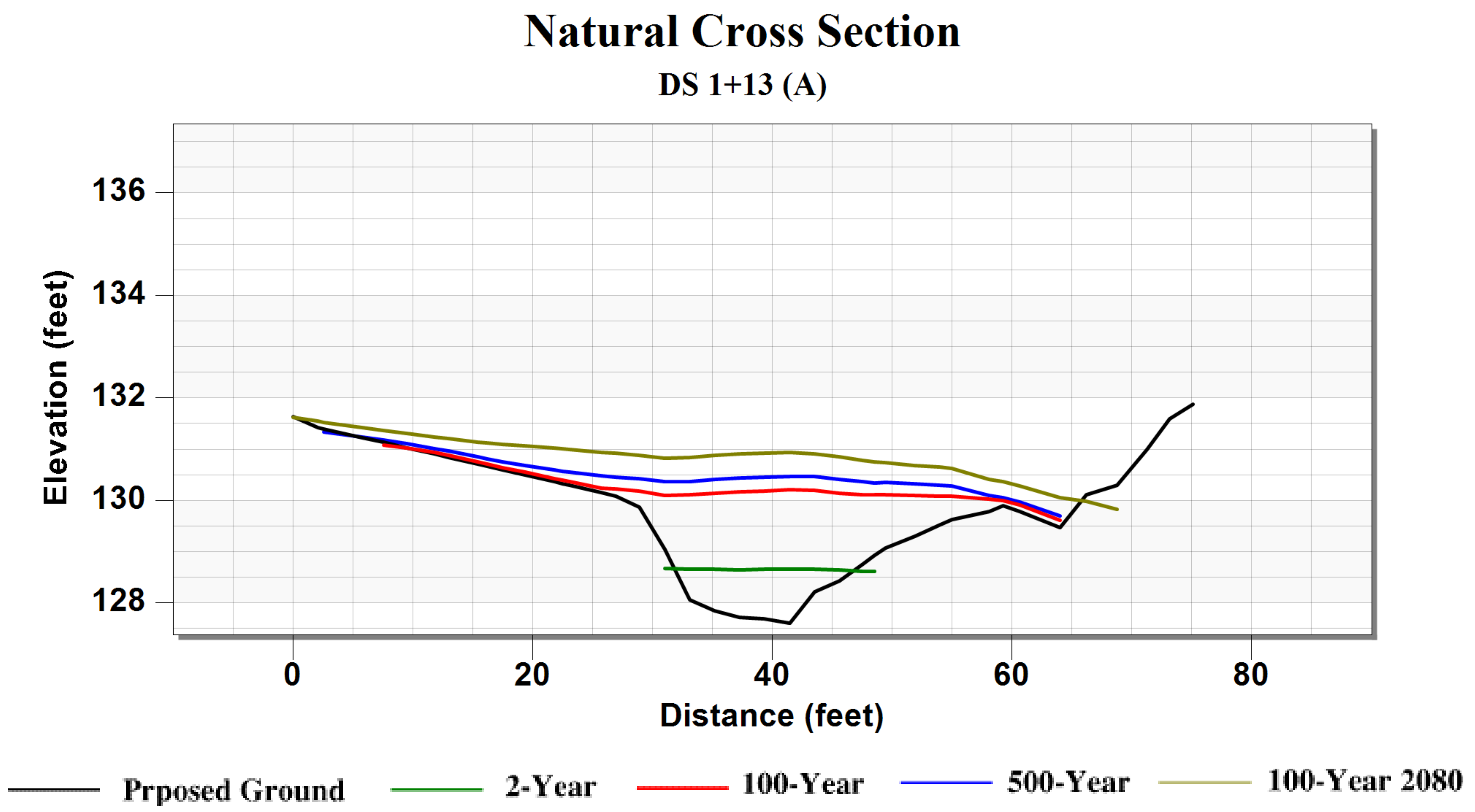


Figure H.51: Natural conditions cross section at downstream station 1+13 (A)

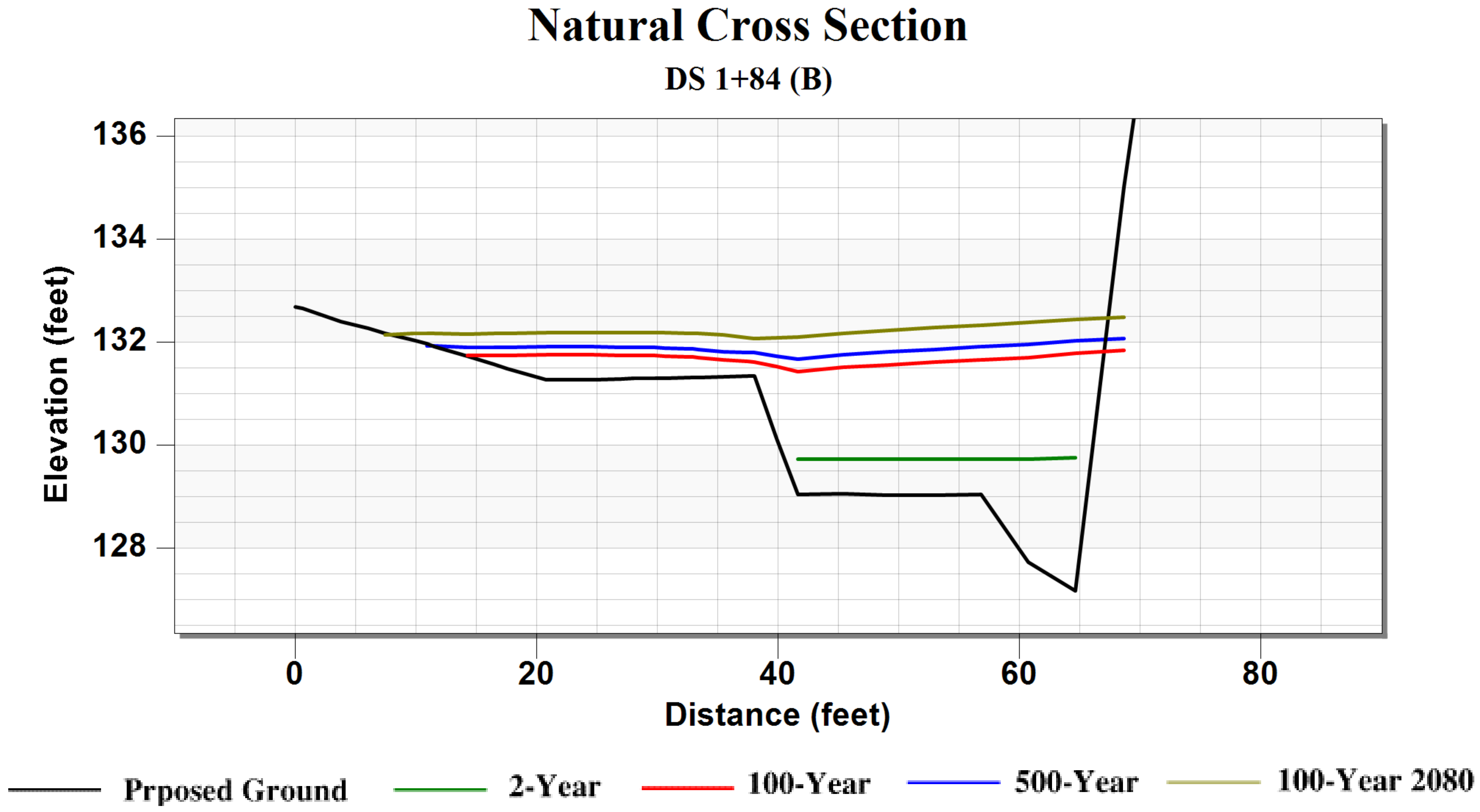


Figure H.52: Natural conditions cross section at downstream station 1+84 (B)

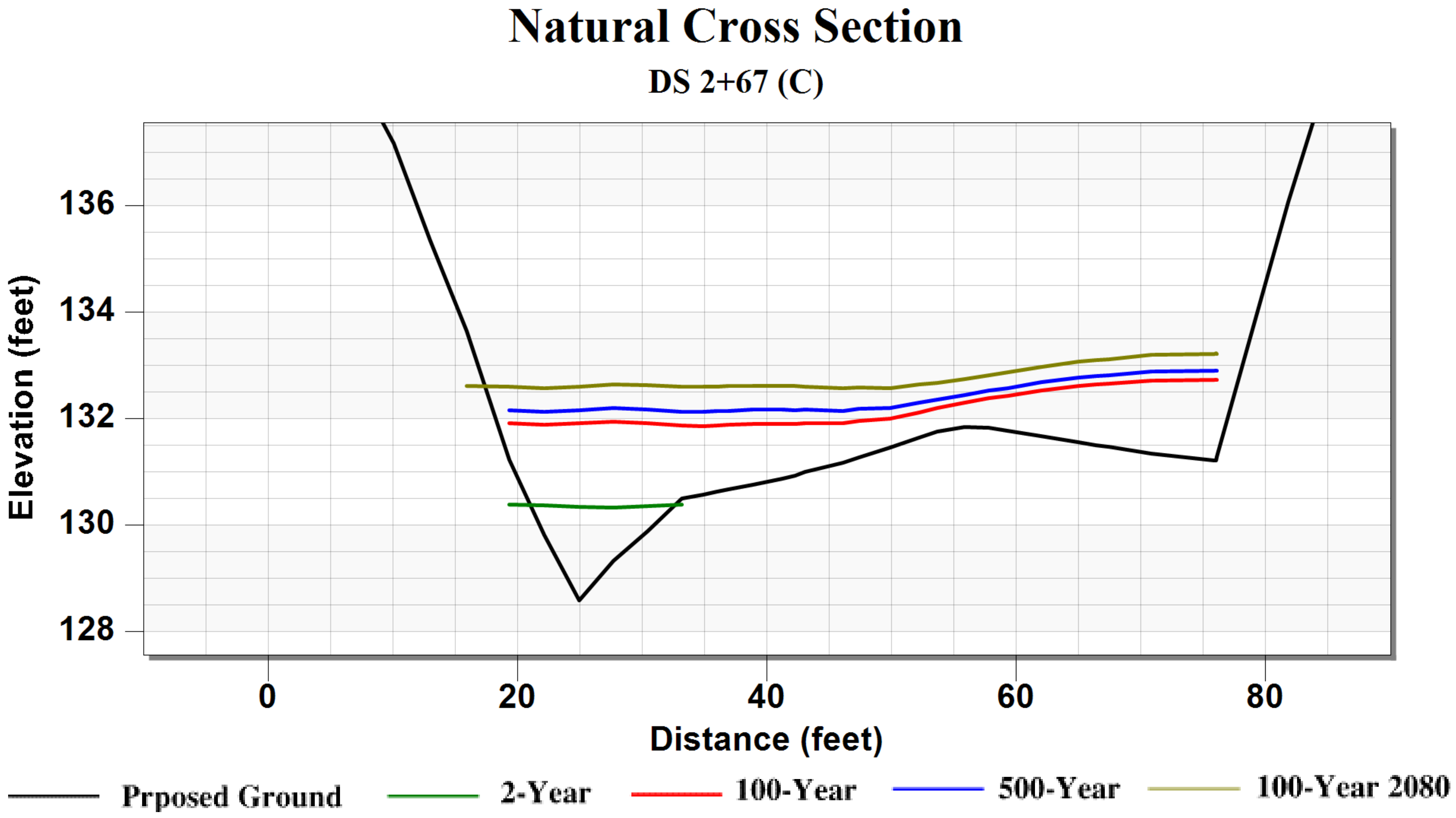


Figure H.53: Natural conditions cross section at downstream station 2+67 (C)

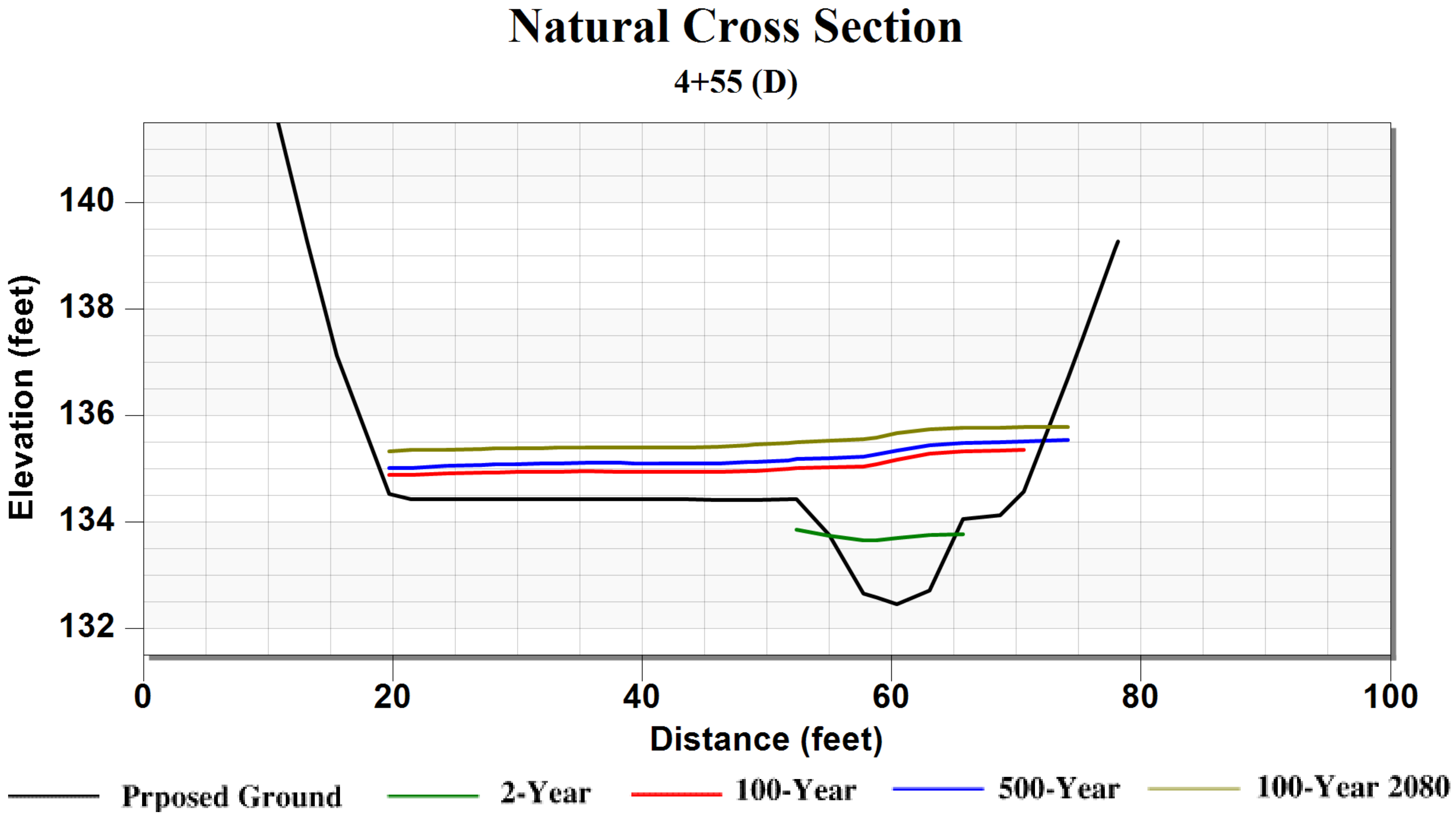


Figure H.54: Natural conditions cross section at station 4+55 (D)

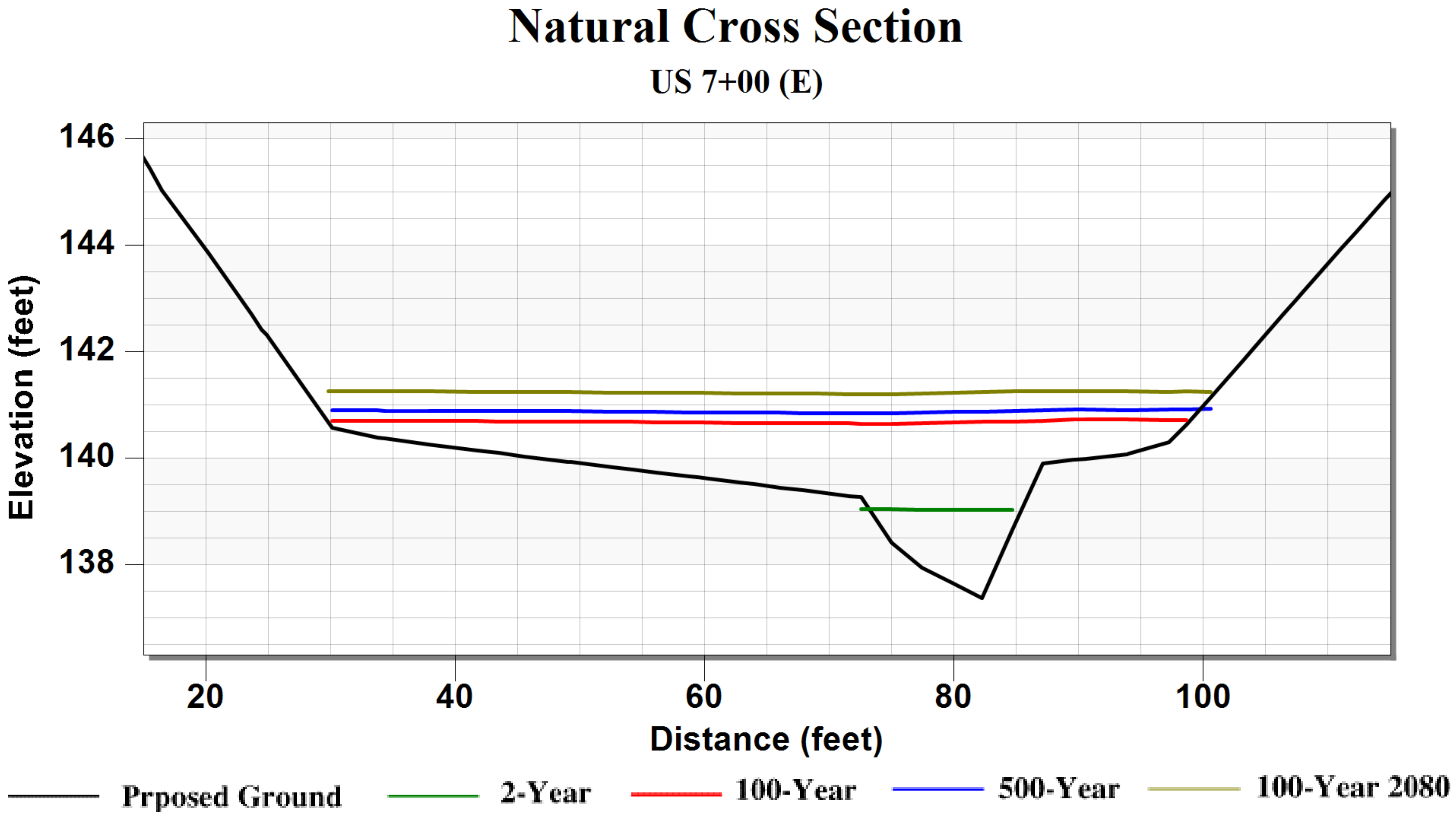


Figure H.55: Natural conditions cross section at upstream station 7+00 (E)

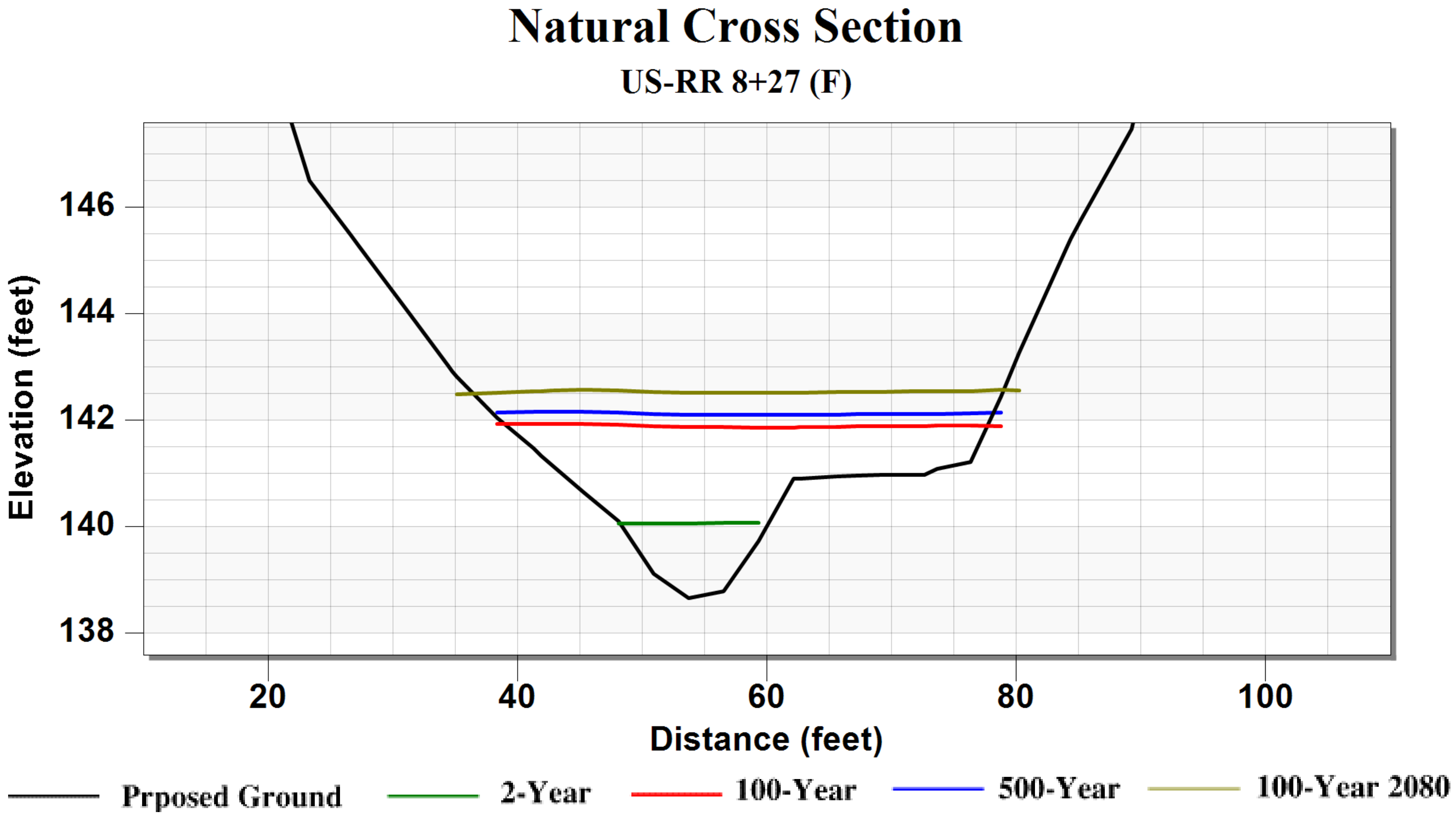


Figure H.56: Natural conditions cross section at upstream station US-RR 8+27 (F)

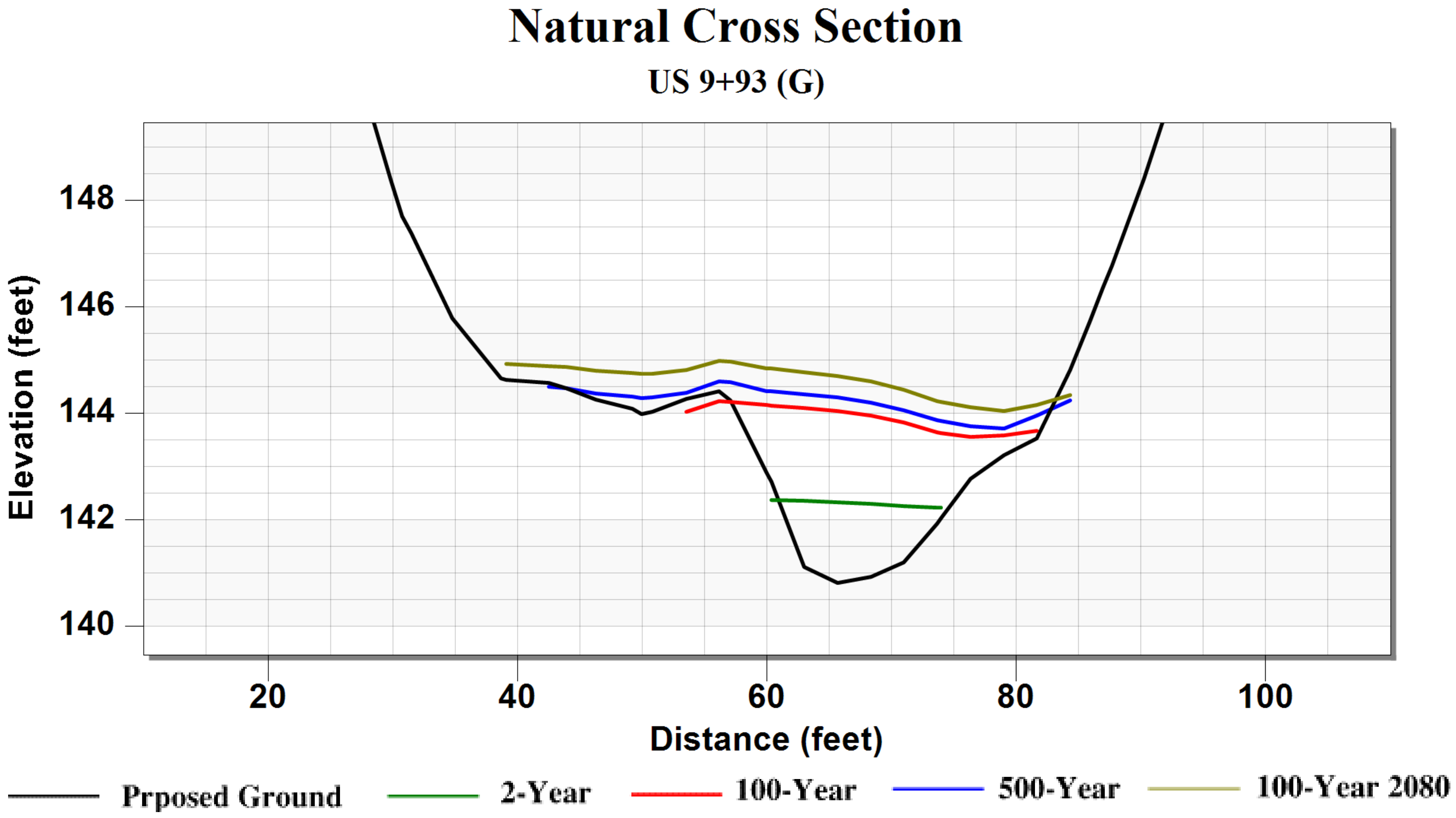


Figure H.57: Natural conditions cross section at upstream station 9+93 (G)

Proposed Conditions SRH-2D Results

Cross Sections

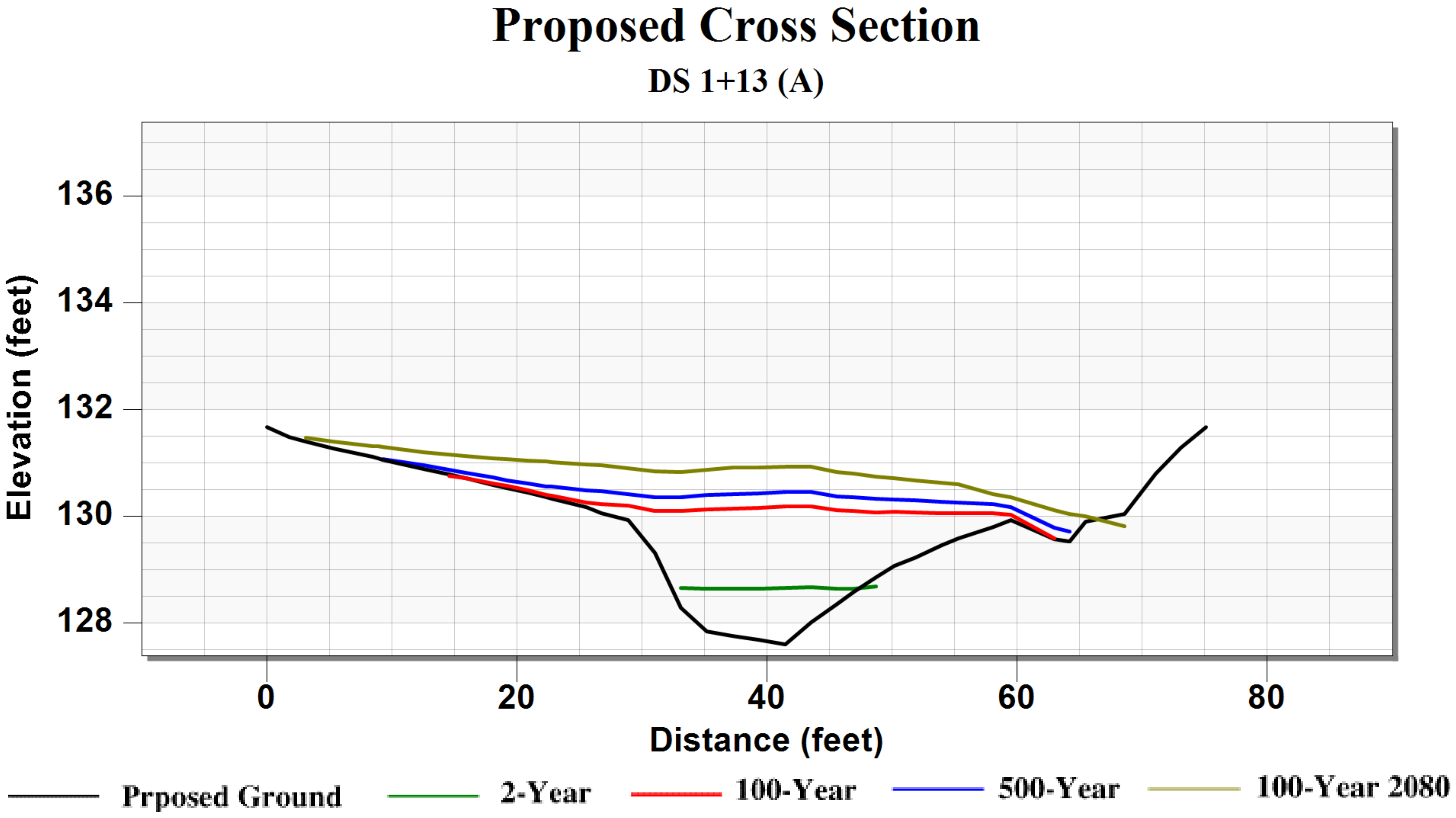


Figure H.58: Proposed conditions cross section at downstream station 1+13 (A)

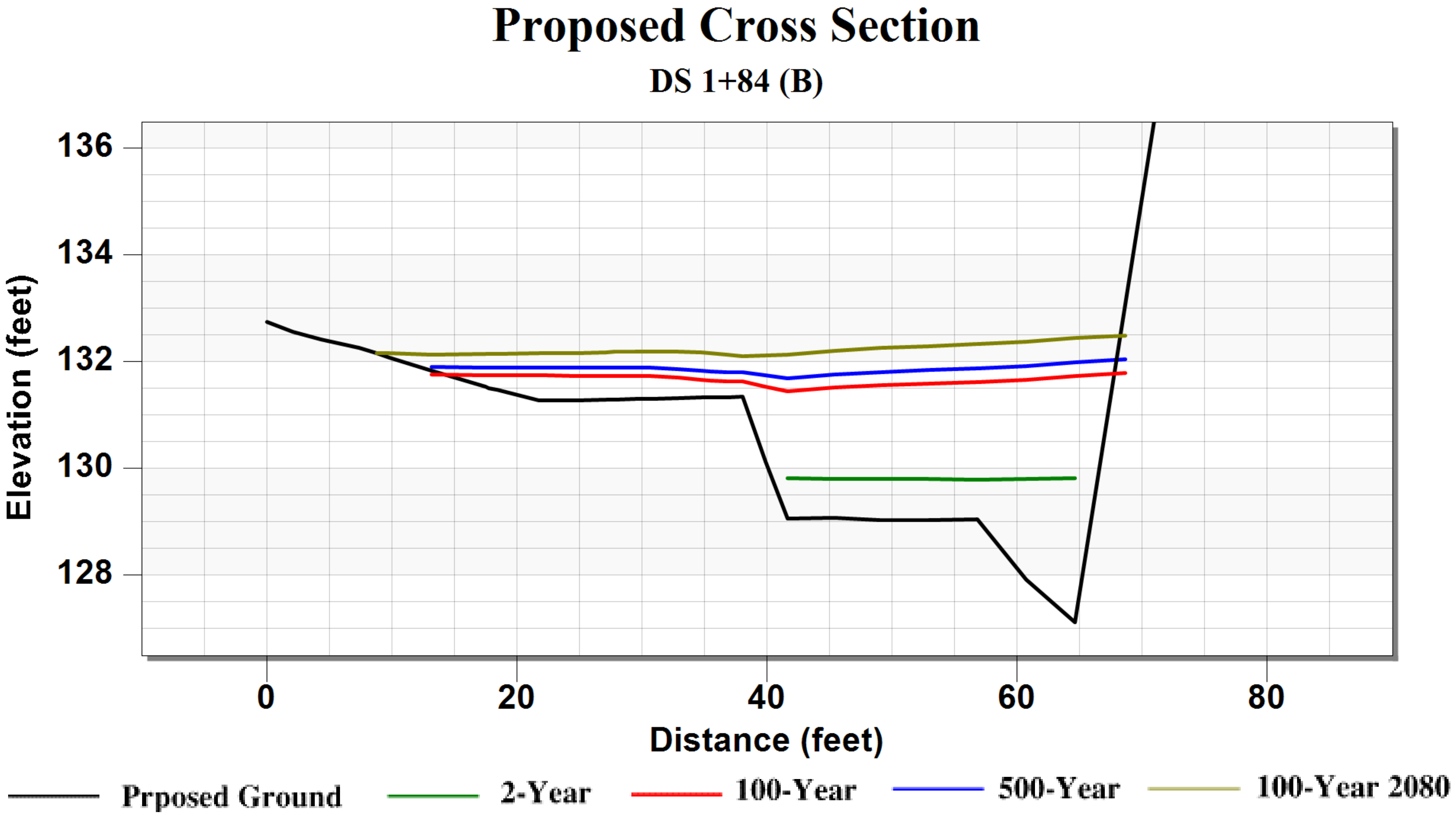


Figure H.59: Proposed conditions cross section at downstream station 1+84 (B)

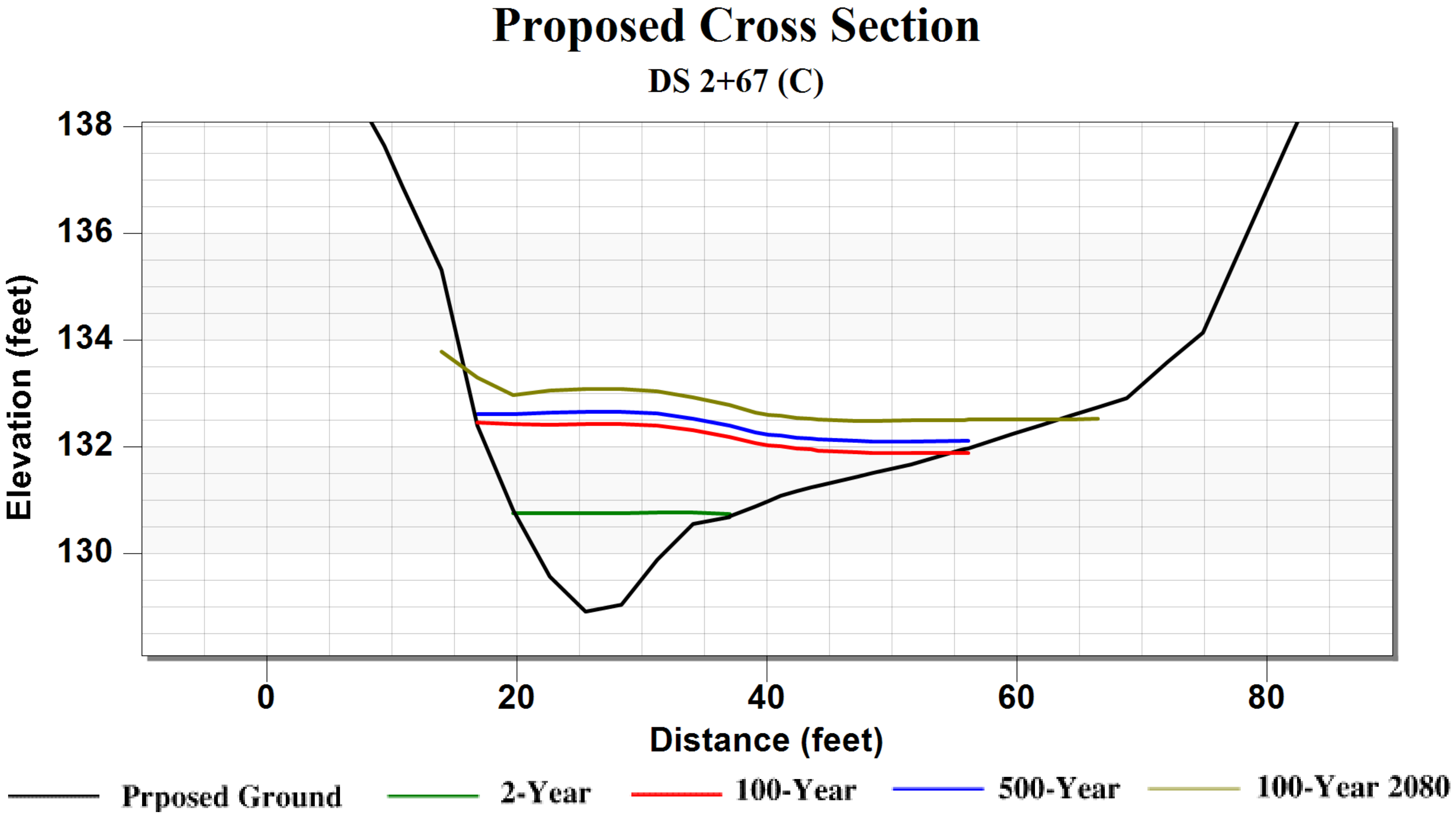


Figure H.60: Proposed conditions cross section at downstream station 2+67 (C)

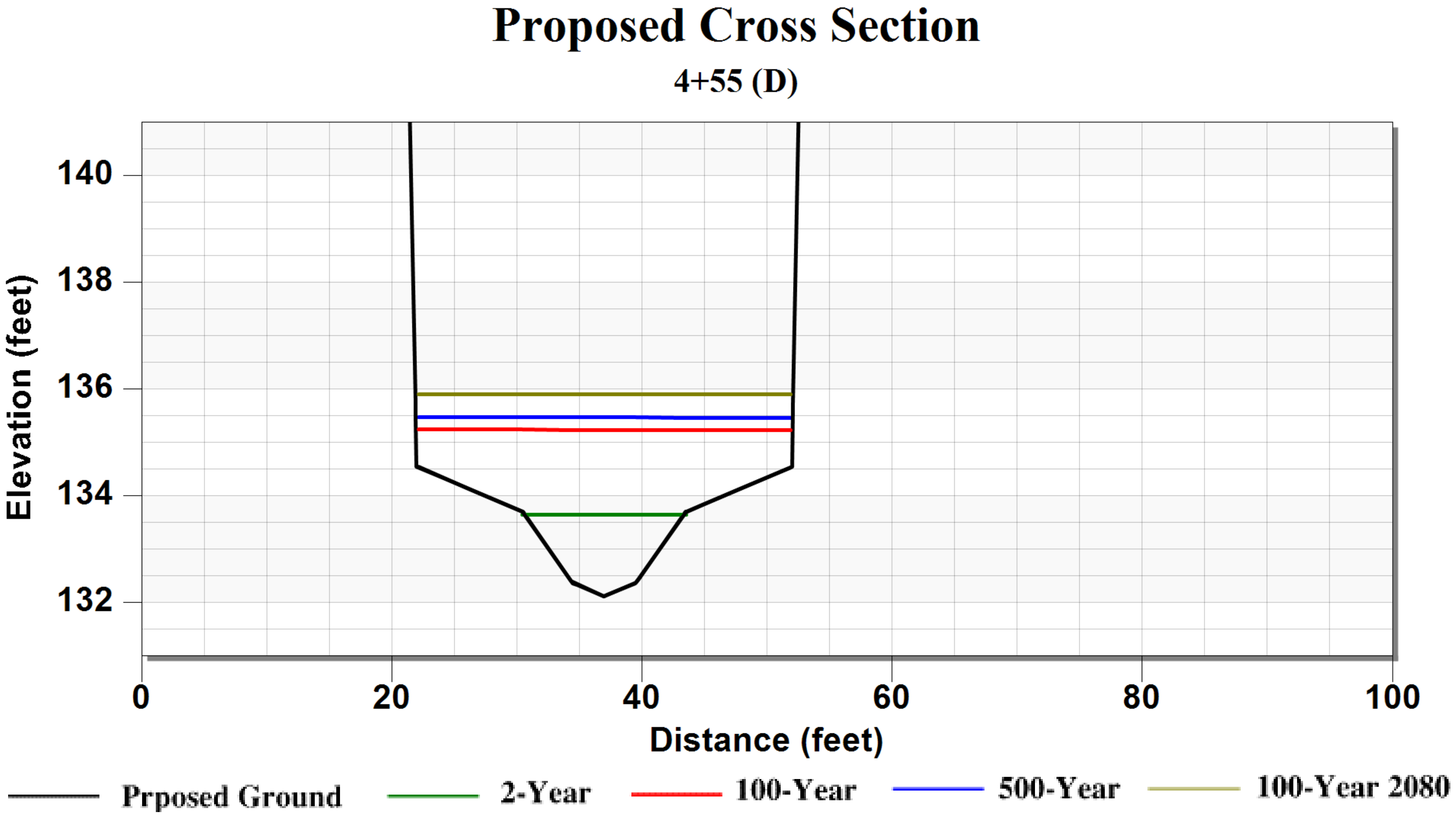


Figure H.61: Proposed conditions cross section at station 4+55 (D)

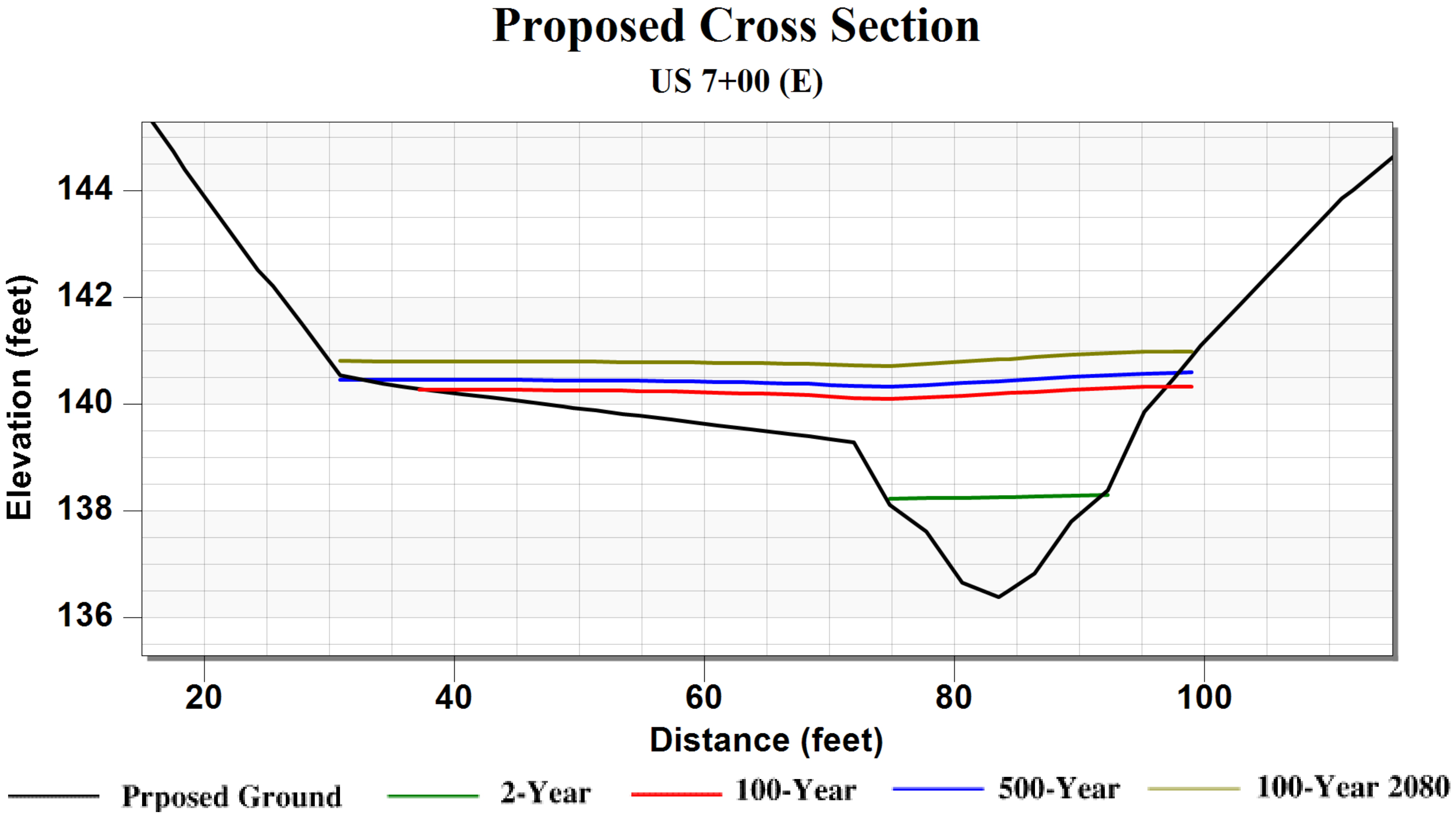


Figure H.62: Proposed conditions cross section at upstream station US 7+00 (E)

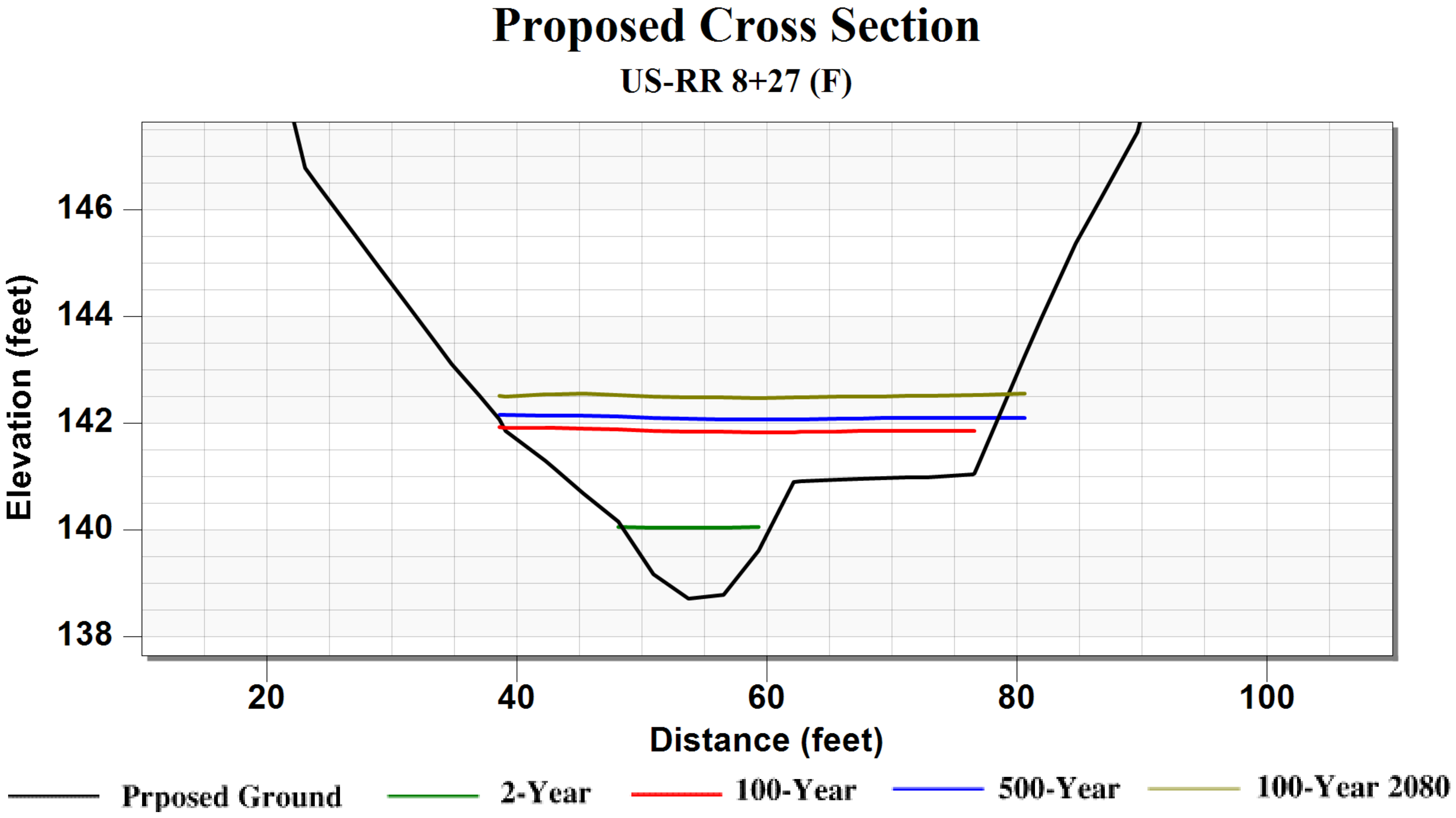


Figure H.63: Proposed conditions cross section at upstream station US-RR 8+27 (F)

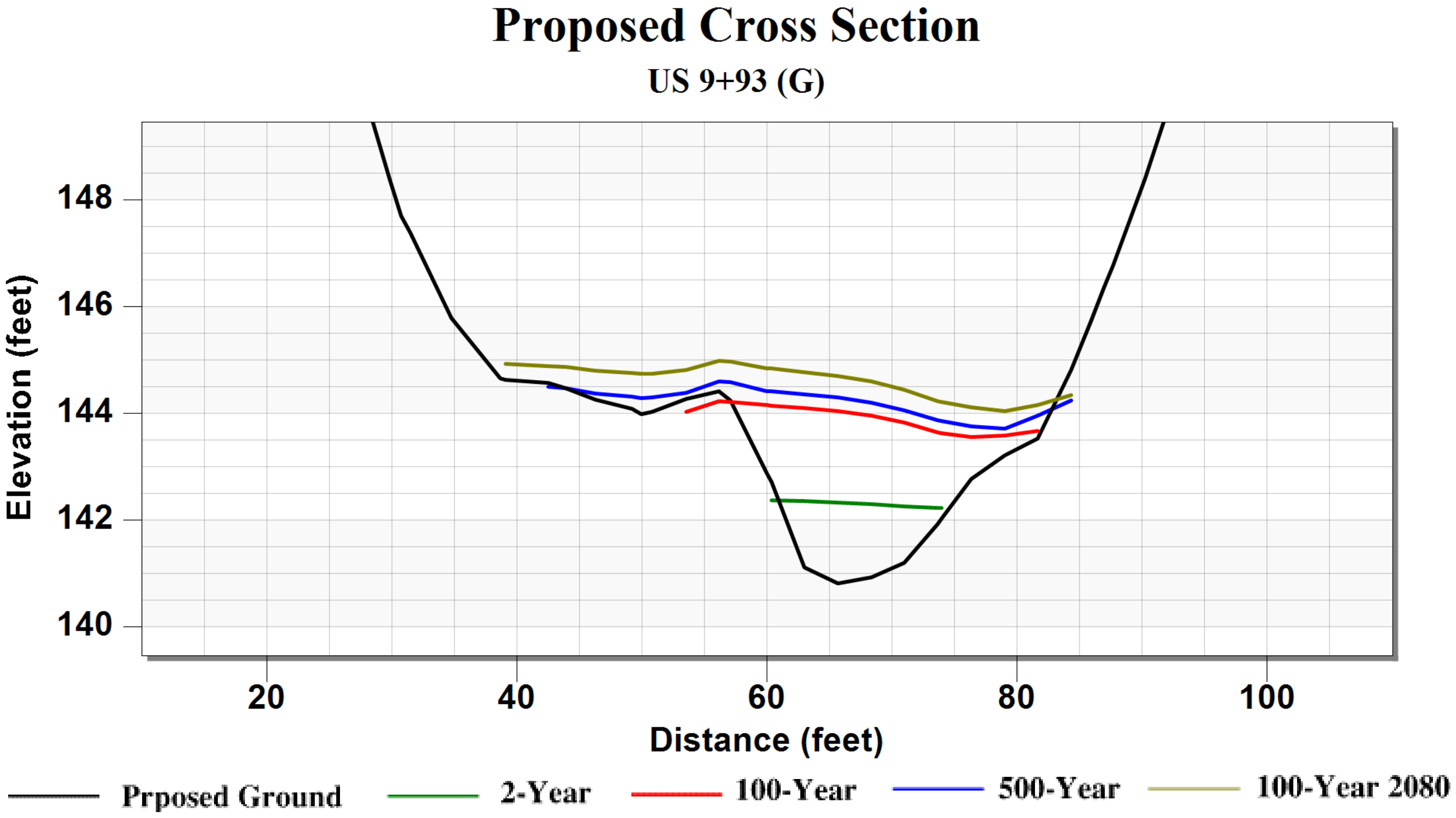
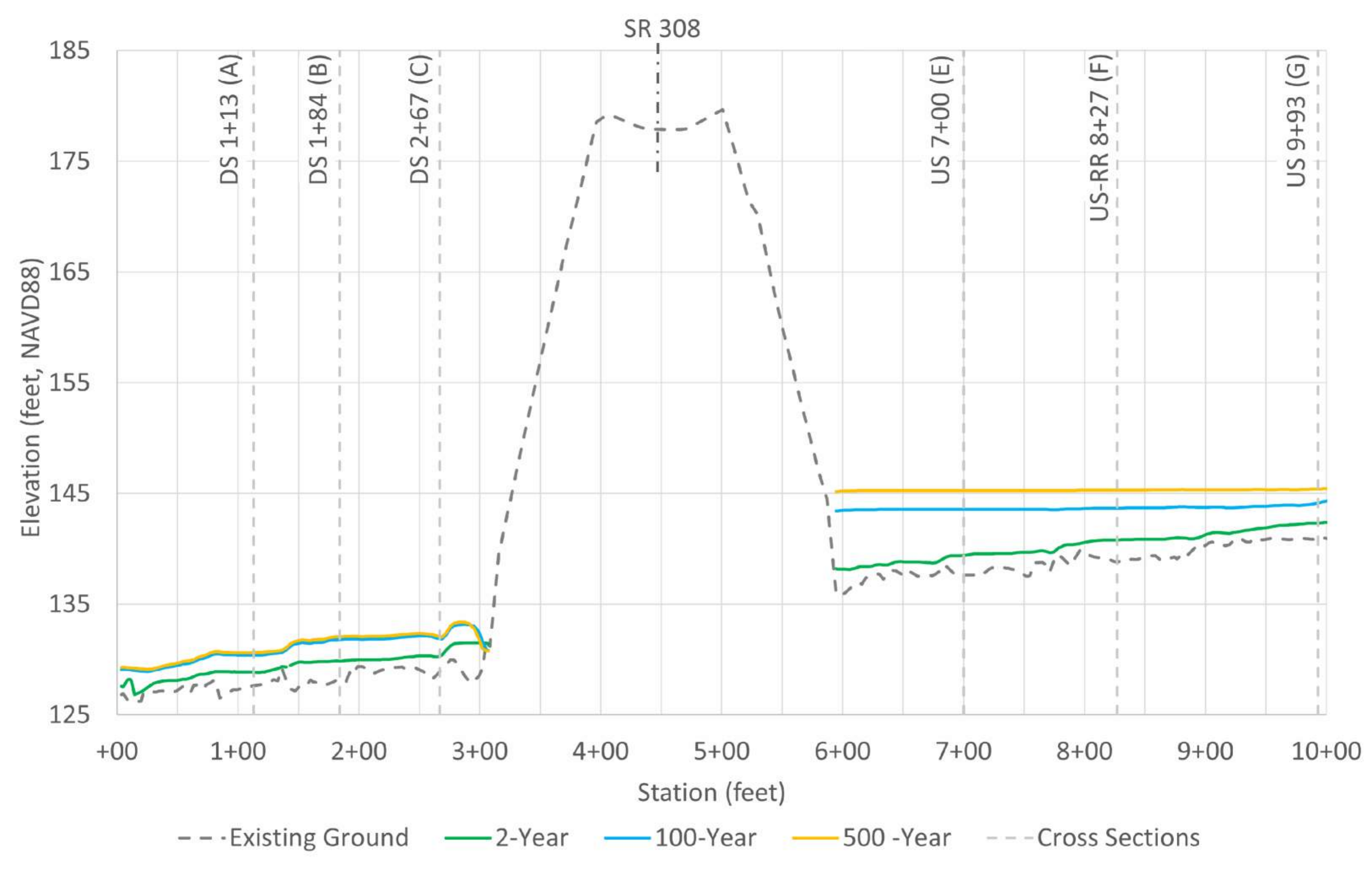


Figure H.64: Proposed conditions cross section at upstream station US 9+93 (G)

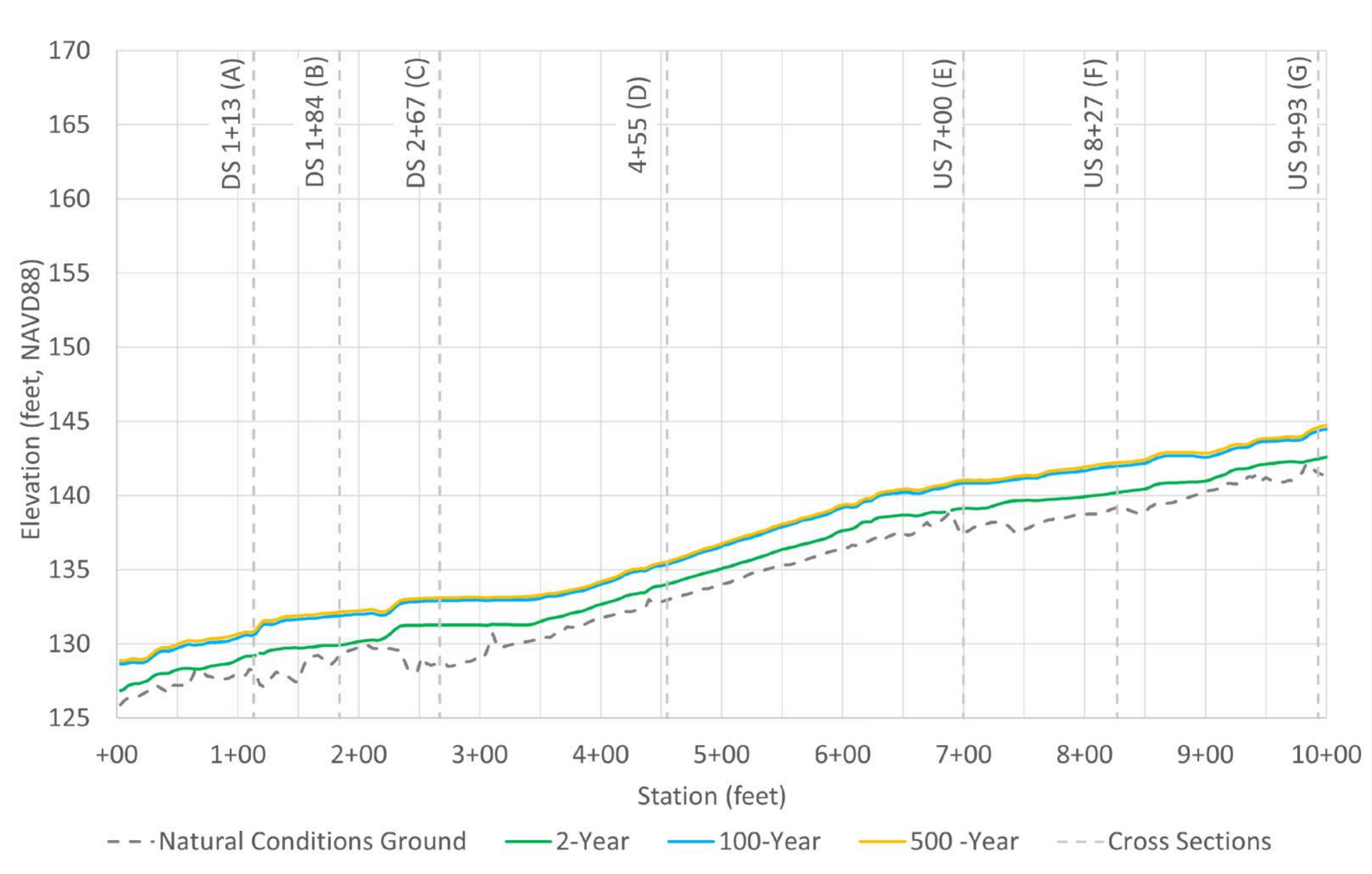
Existing Conditions SRH-2D Results

Water Surface Profile


SR 308
185
175
165
155
145
135
125
Elevation (feet, NAVD88)
DS 1+13 (A)
DS 1+84 (B)
DS 2+67 (C)
US 7+00 (E)
US-RR 8+27 (F)
US 9+93 (G)
+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
Station (feet)
Existing Ground
2-Year
100-Year
500 -Year
Cross Sections

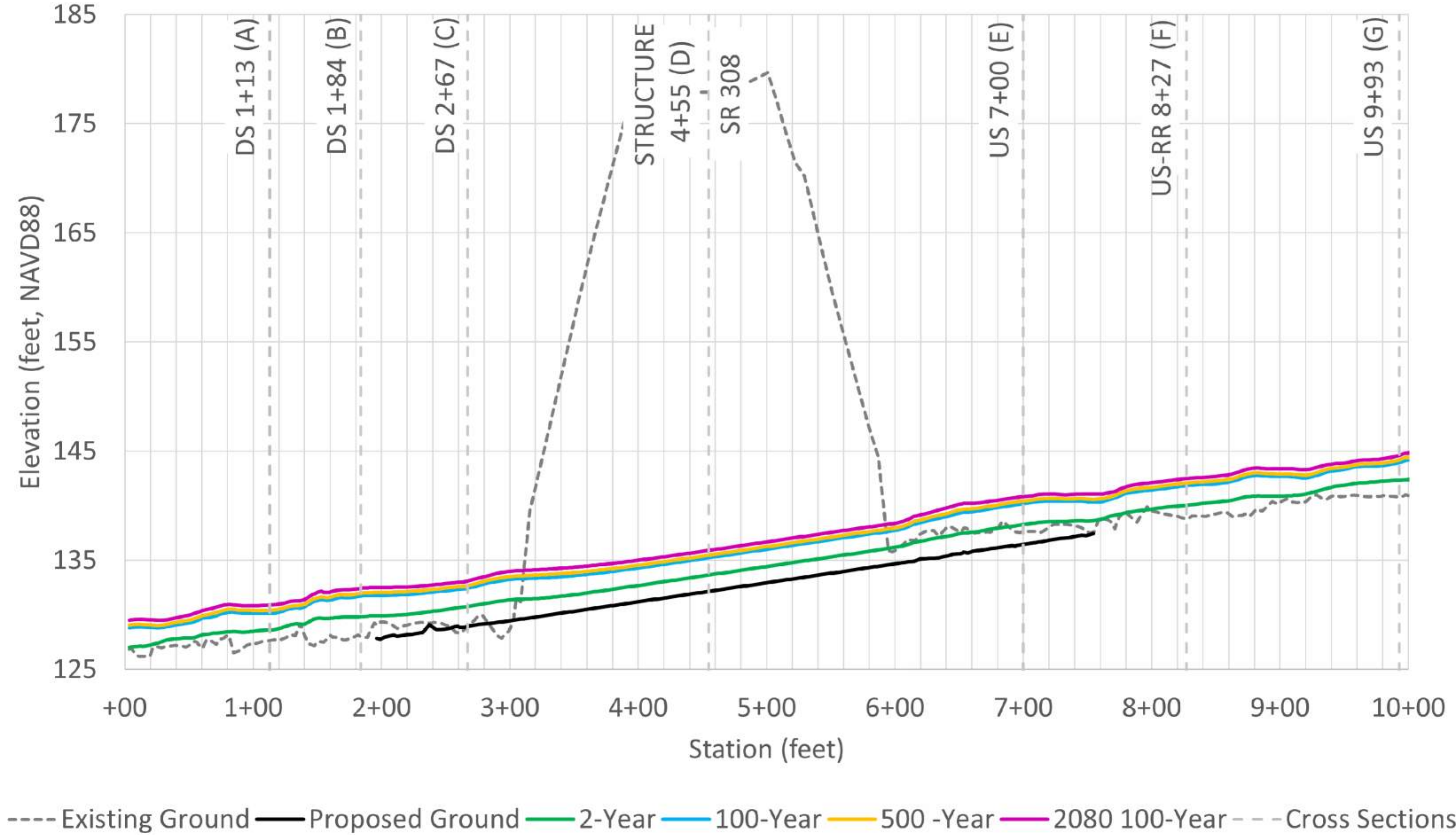
Natural Conditions SRH-2D Results

Water Surface Profile


DS 1+13 (A)
DS 1+84 (B)
DS 2+67 (C)
4+55 (D)
US 7+00 (E)
US 8+27 (F)
US 9+93 (G)
Elevation (feet, NAVD88)
170
165
160
155
150
145
140
135
130
125
+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
Station (feet)
Natural Conditions Ground
2-Year
100-Year
500 -Year
Cross Sections

Proposed Conditions SRH-2D Results

Water Surface Profile



185
175
165
155
145
135
125
Elevation (feet, NAVD88)
DS 1+13 (A)
DS 1+84 (B)
DS 2+67 (C)
STRUCTURE
4+55 (D)
SR 308
US 7+00 (E)
US-RR 8+27 (F)
US 9+93 (G)
+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
Station (feet)
Existing Ground
Proposed Ground
2-Year
100-Year
500 -Year
2080 100-Year
Cross Sections

Appendix I: SRH-2D Model Stability and Continuity

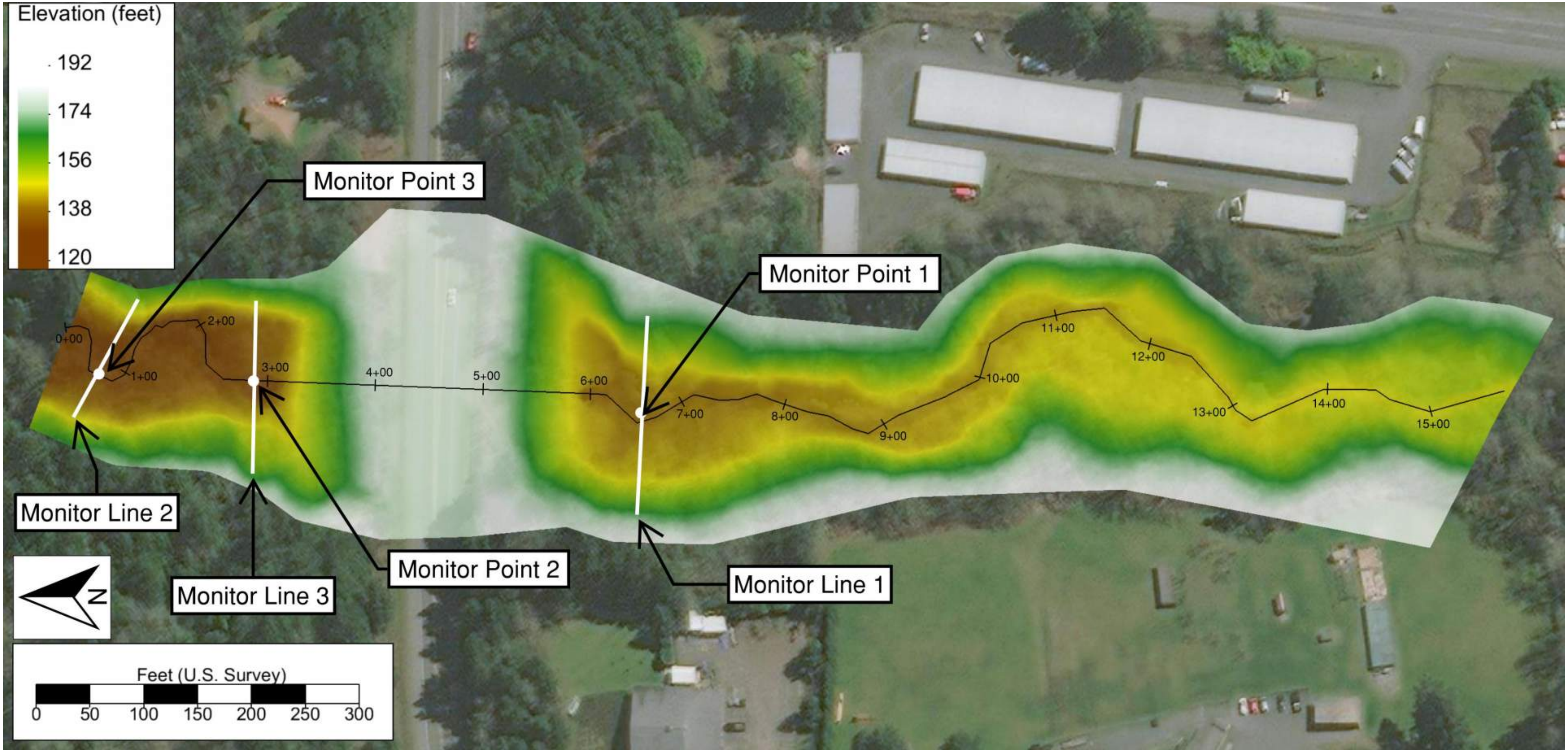


Figure I.1: Existing conditions monitor points and lines

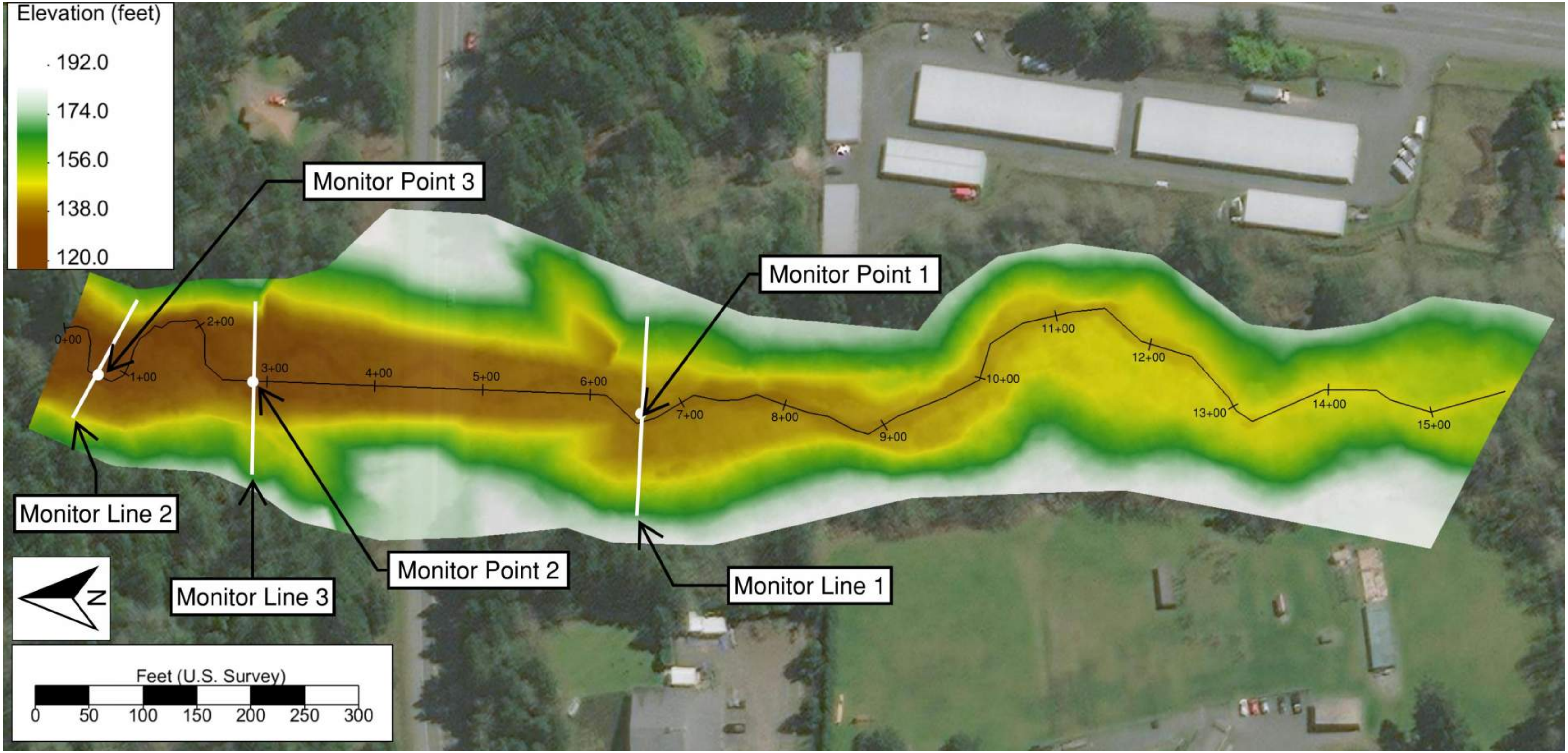


Figure I.2: Natural conditions monitor points and lines

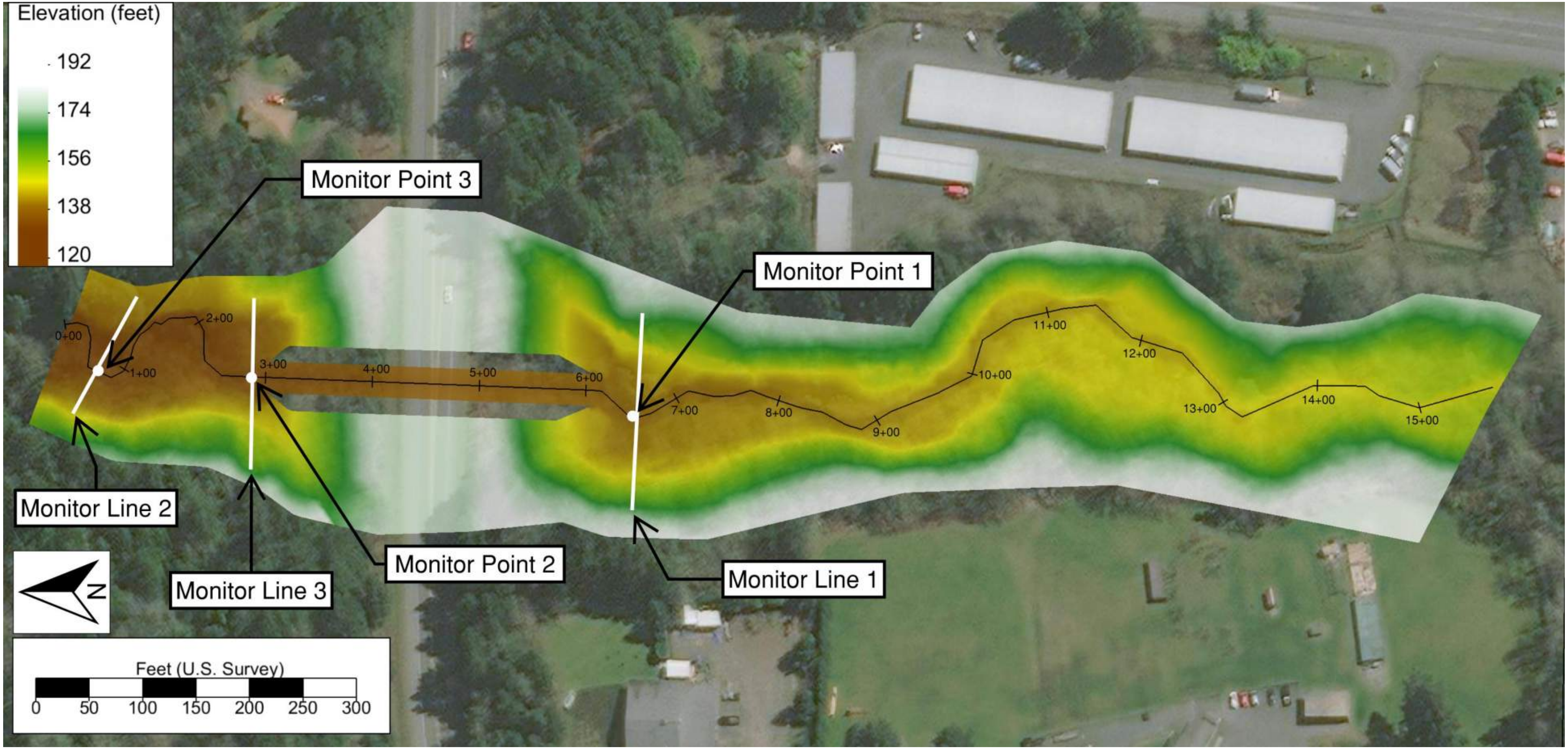


Figure I.3: Proposed conditions monitor points and lines

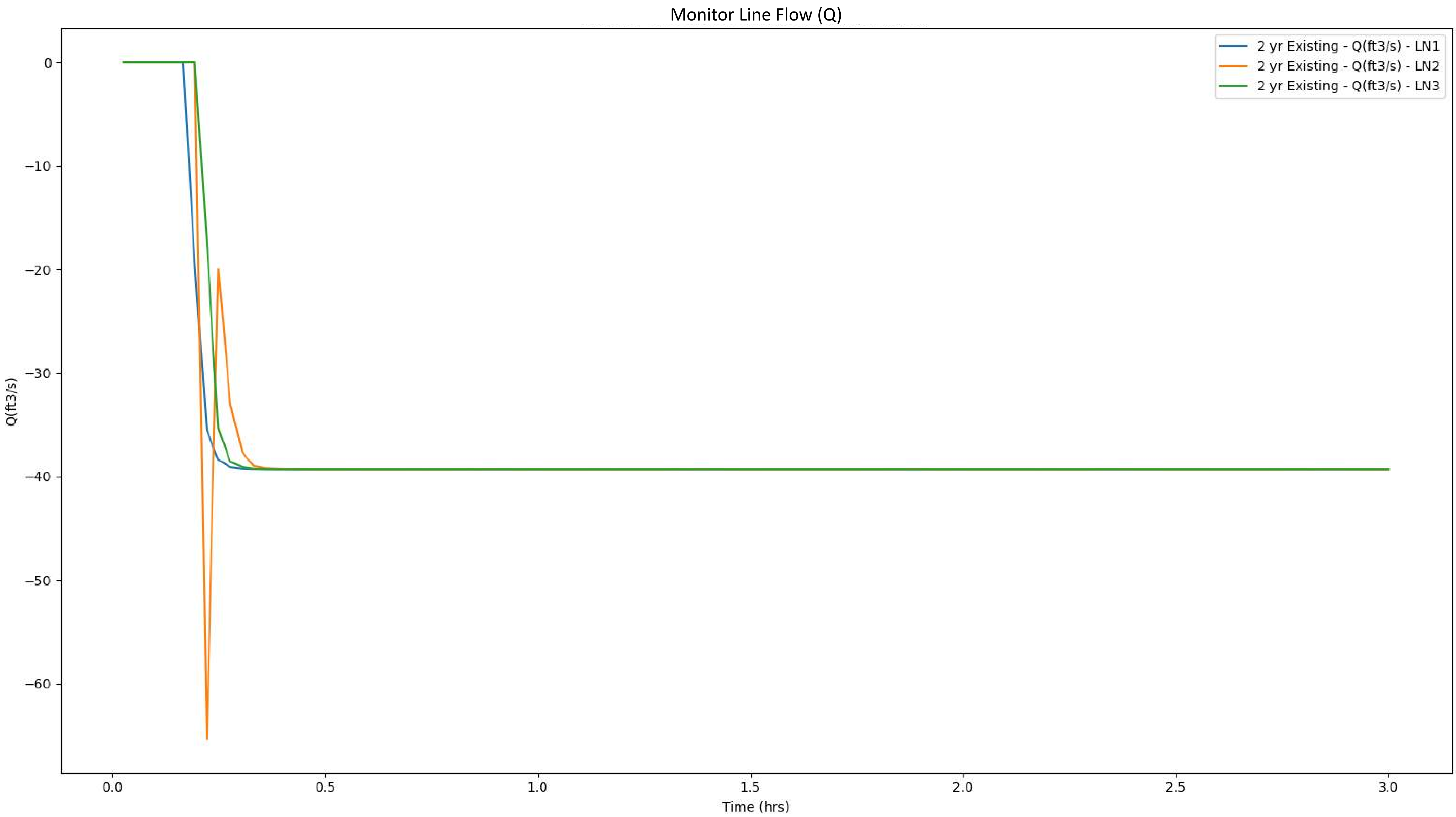


Figure I.4: Existing conditions 2-year monitor lines

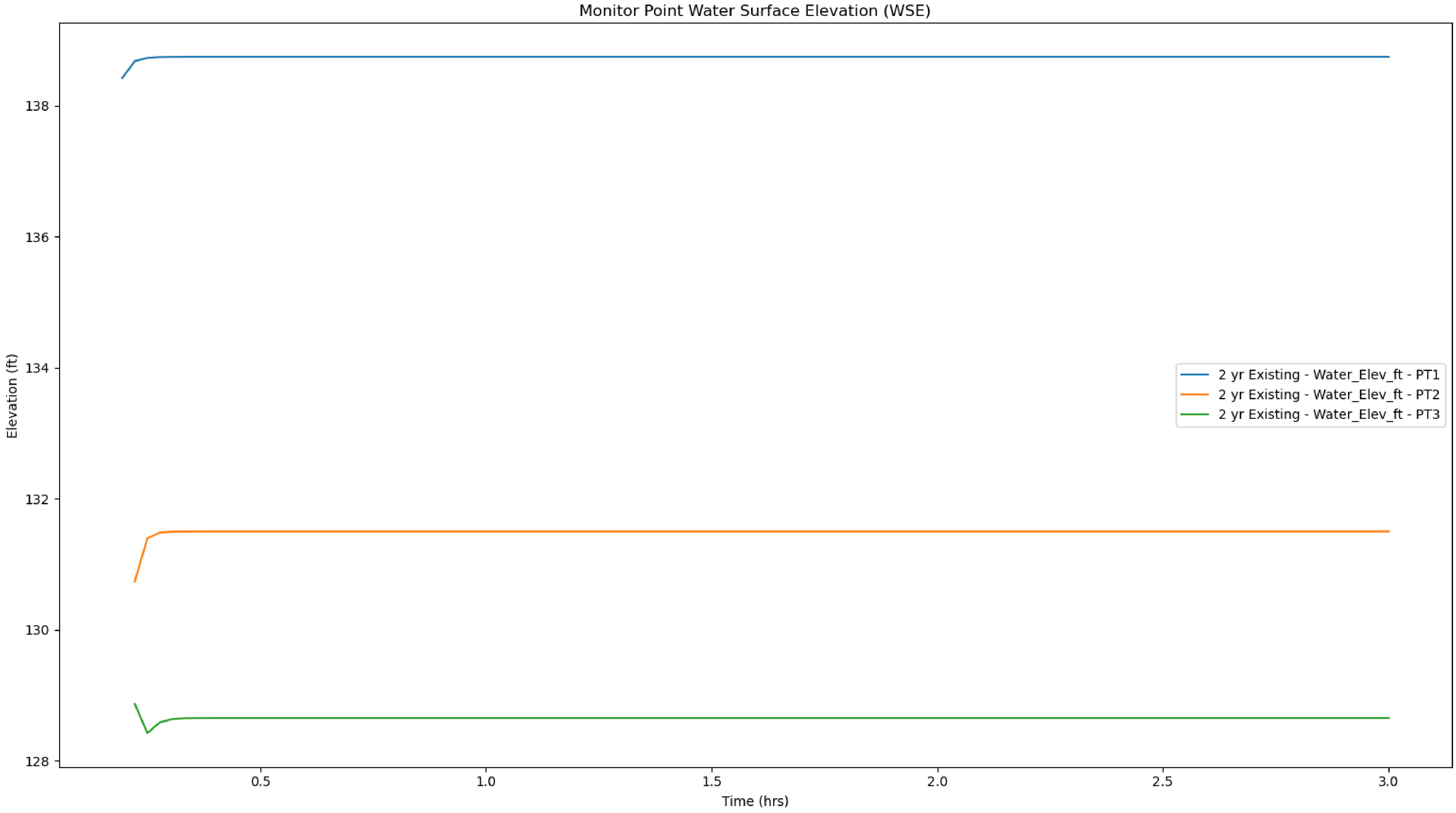


Figure I.5: Existing conditions 2-year monitor points

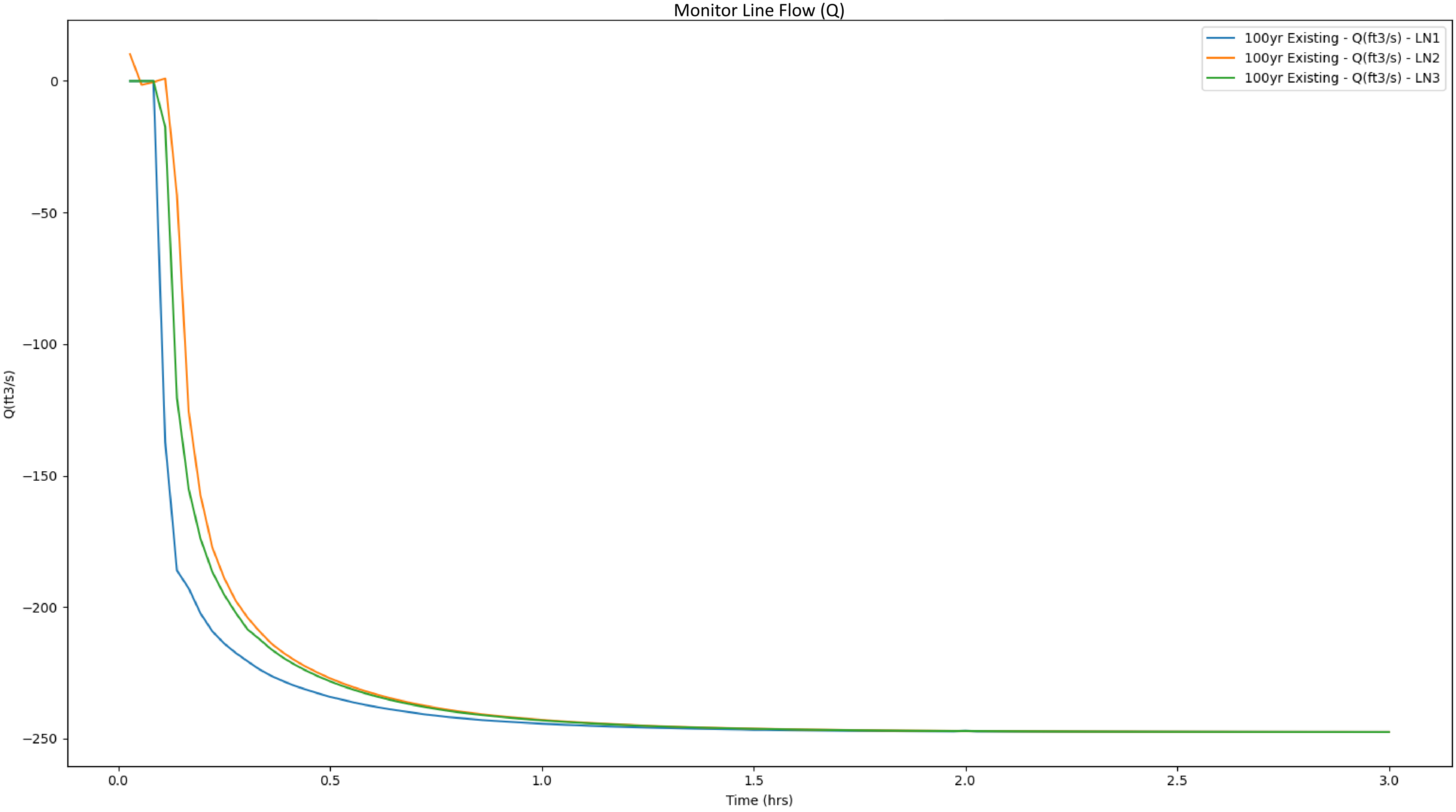


Figure I.6: Existing conditions 100-year monitor lines

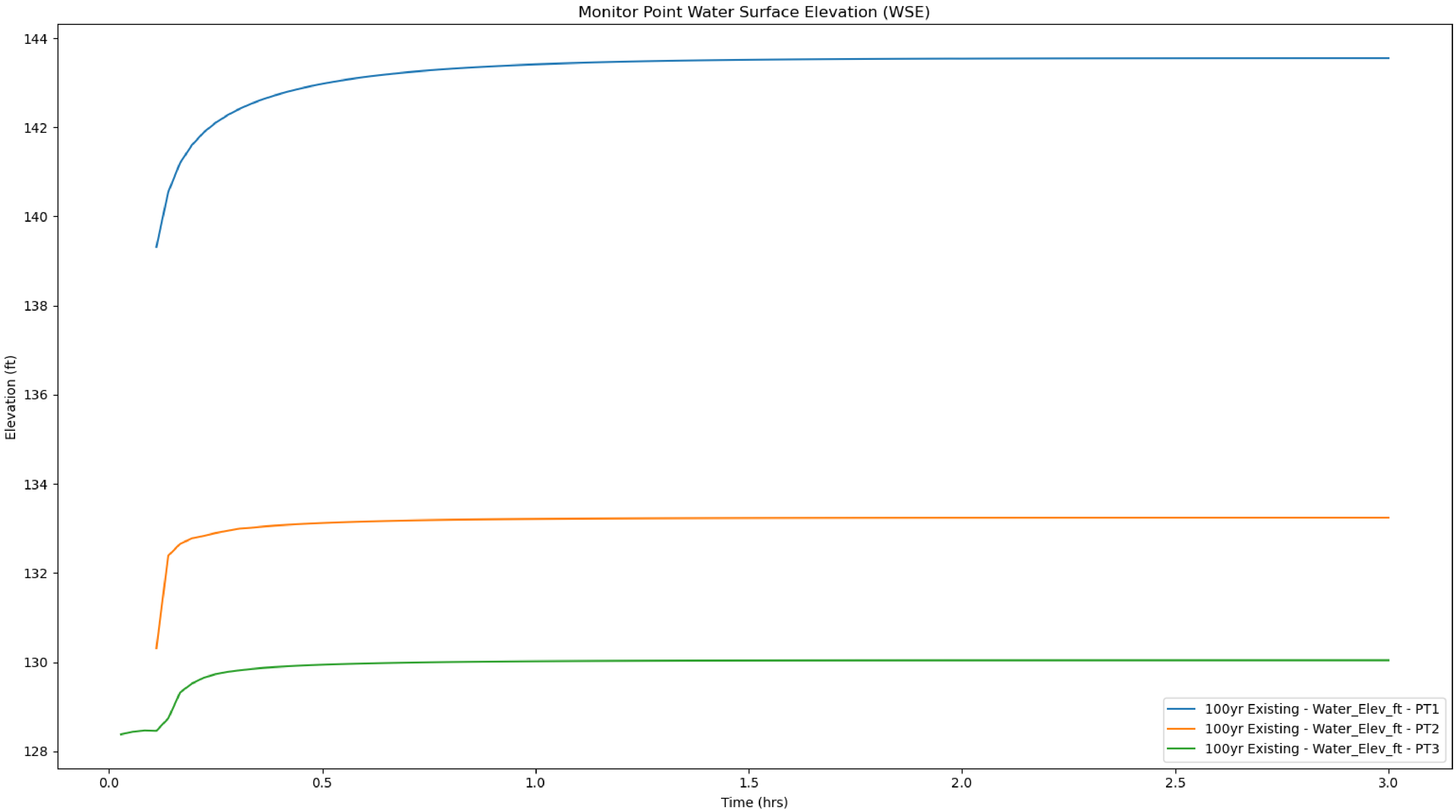


Figure I.7: Existing conditions 100-year monitor points

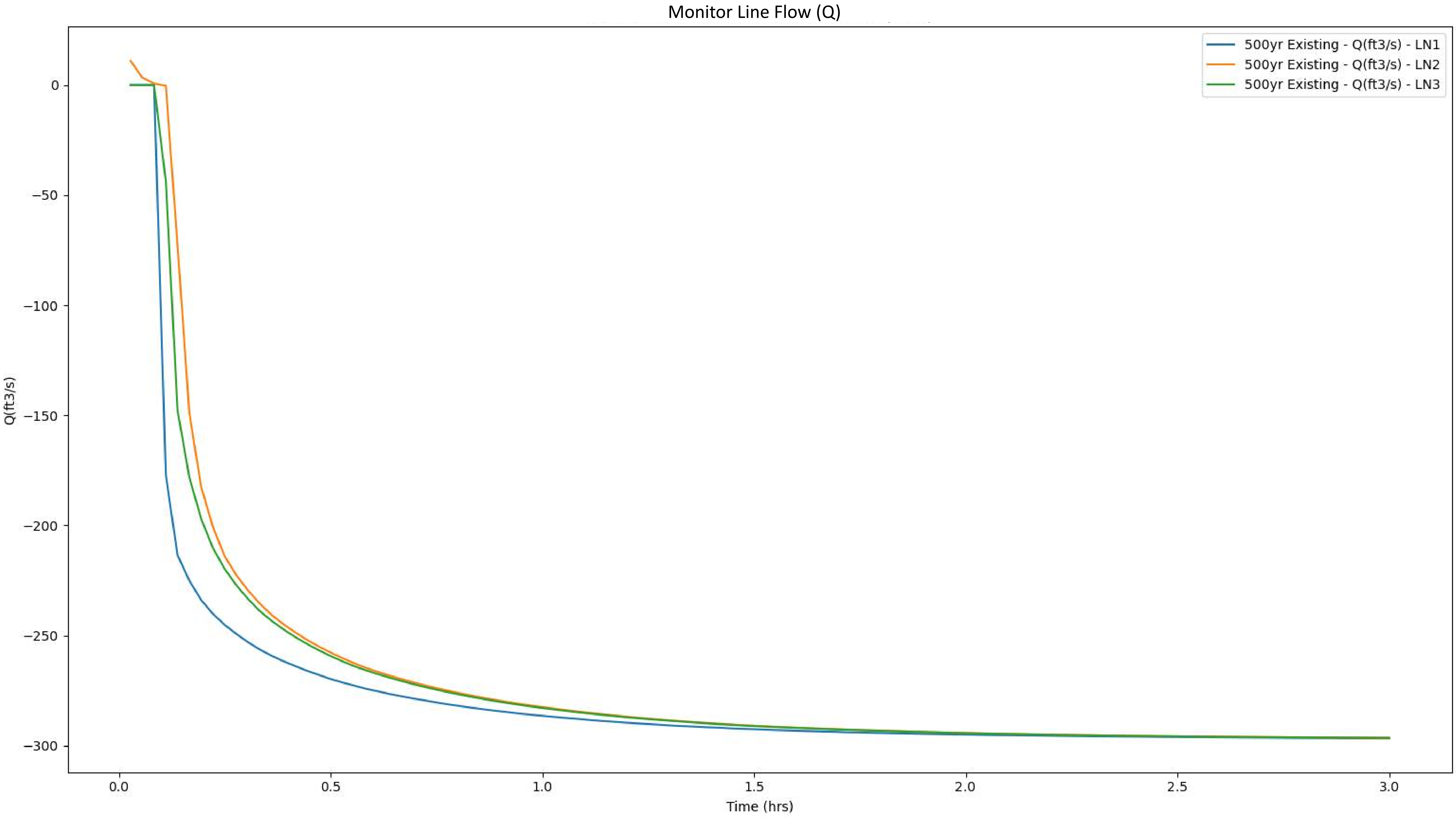


Figure I.8: Existing conditions 500-year monitor lines

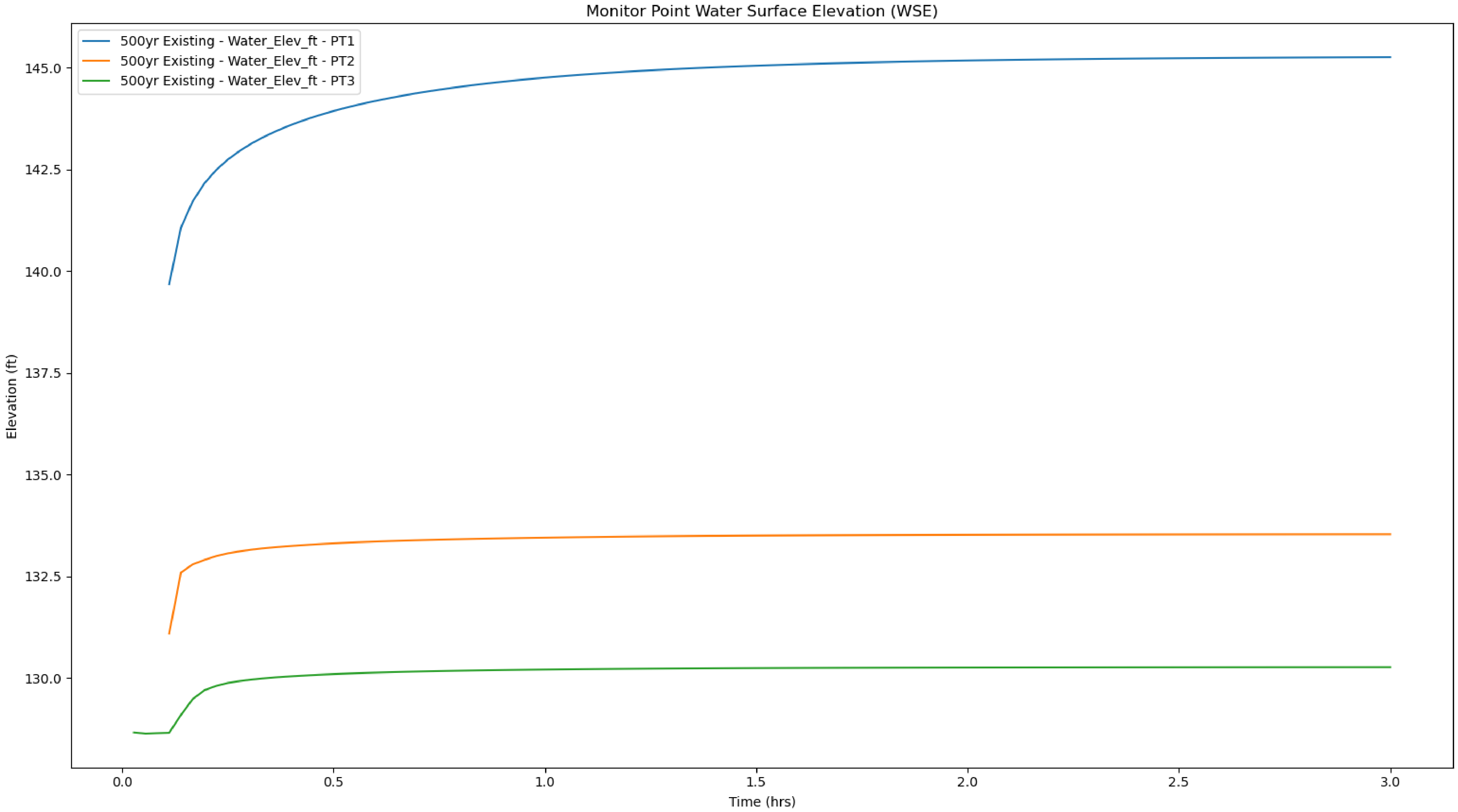


Figure I.9: Existing conditions 500-year monitor points

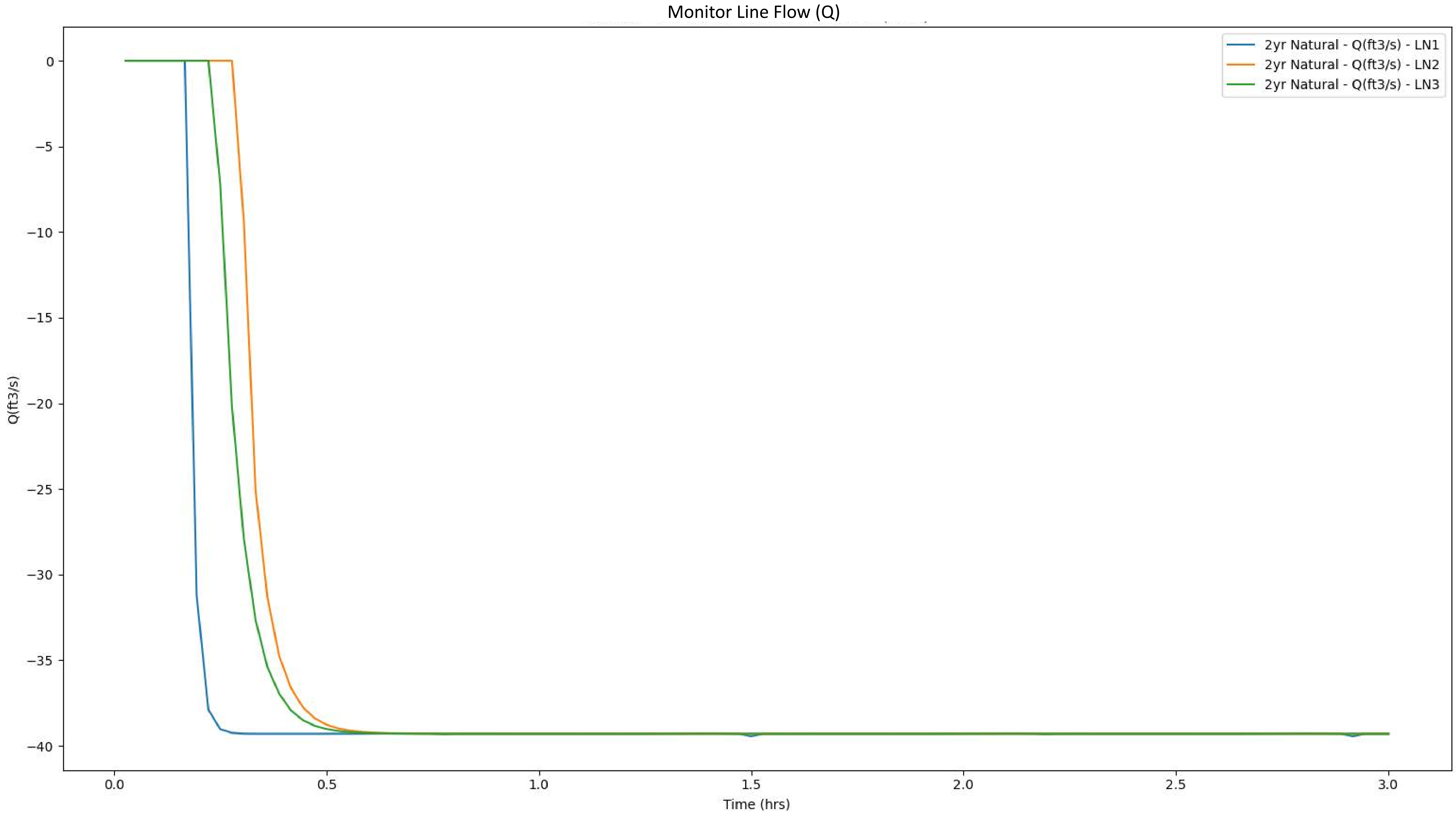


Figure I.10: Natural conditions 2-year monitor lines

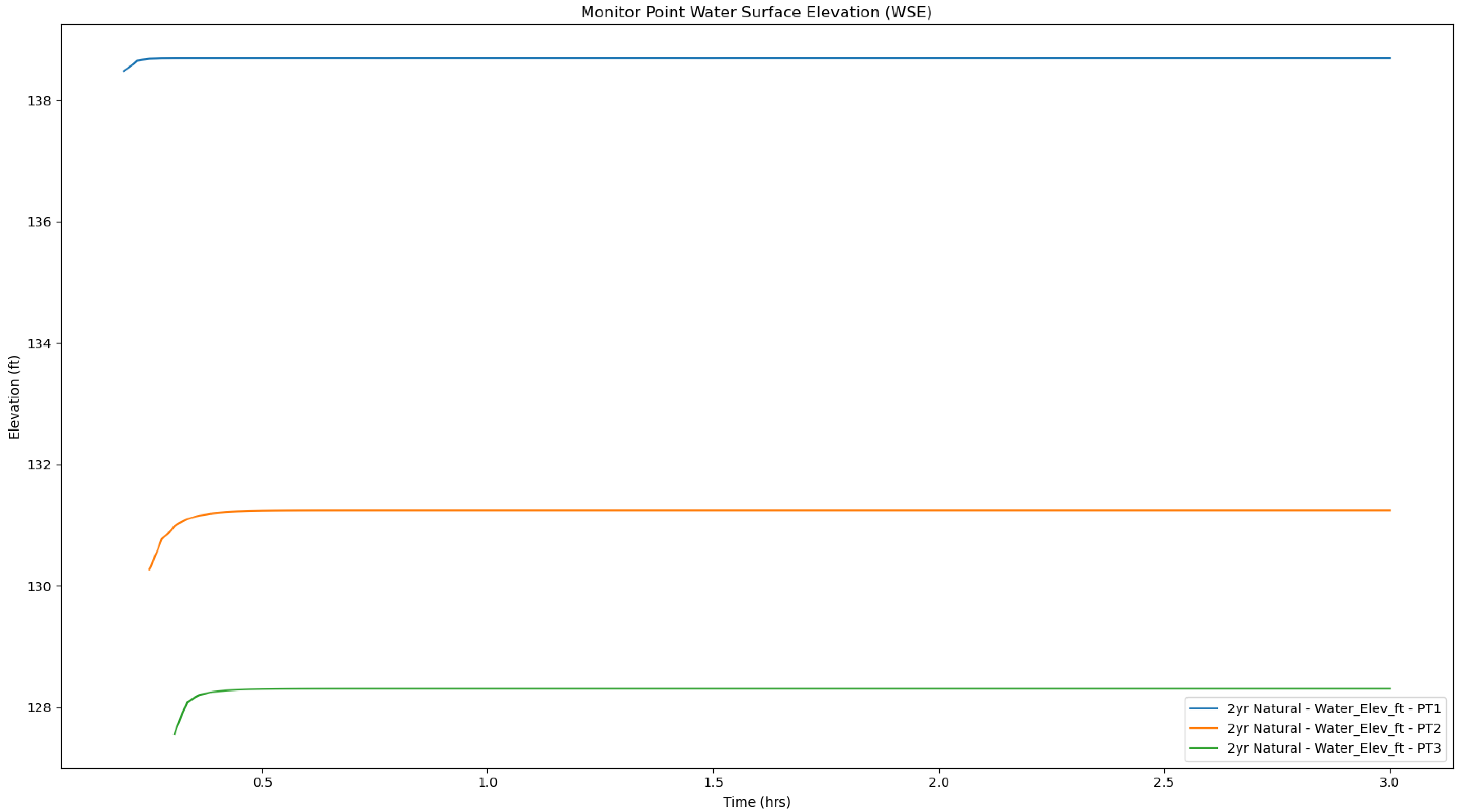


Figure I.11: Natural conditions 2-year monitor points

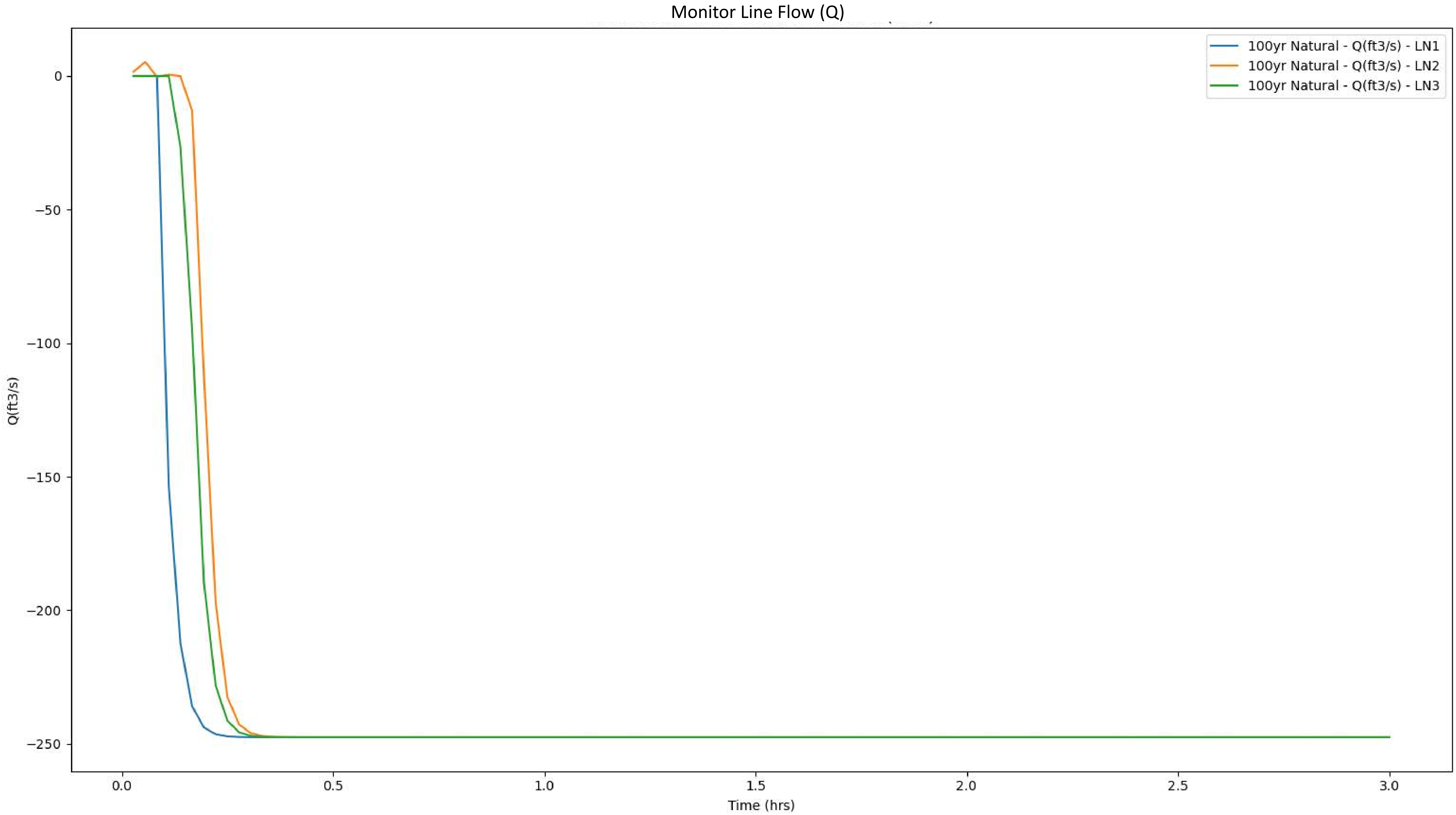


Figure I.12: Natural conditions 100-year monitor lines

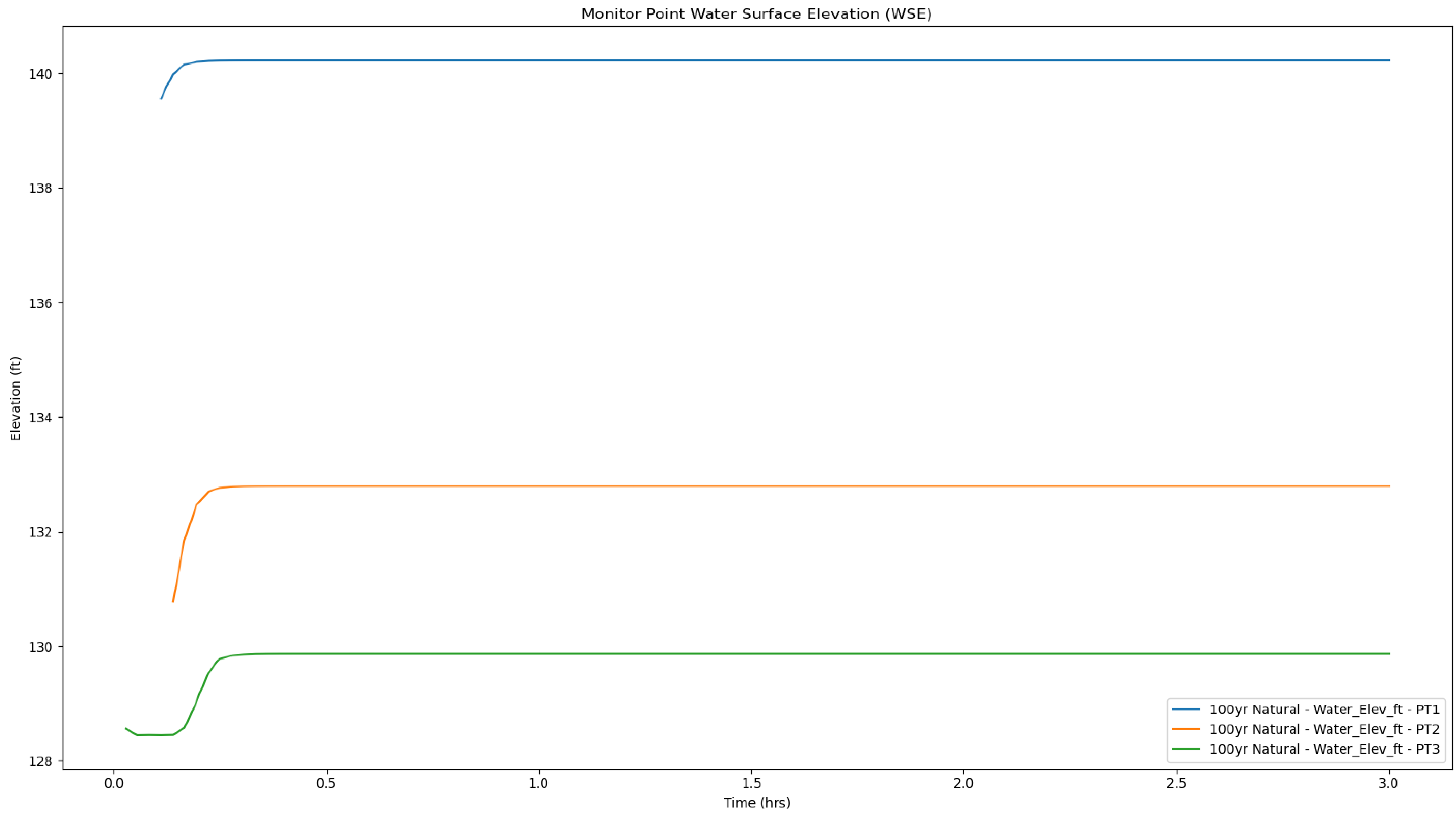


Figure I.13: Natural conditions 100-year monitor points

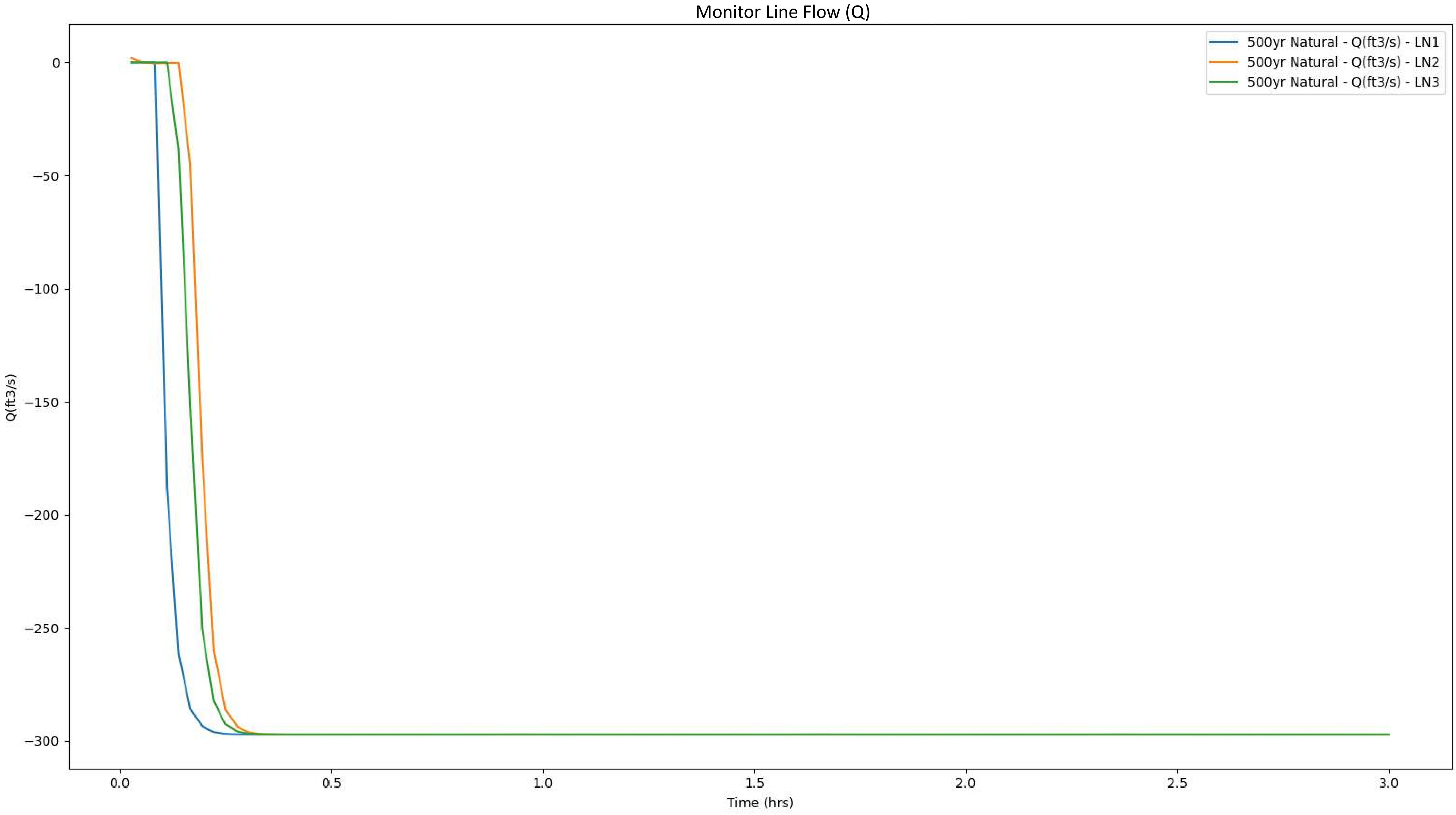


Figure I.14: Natural conditions 500-year monitor lines

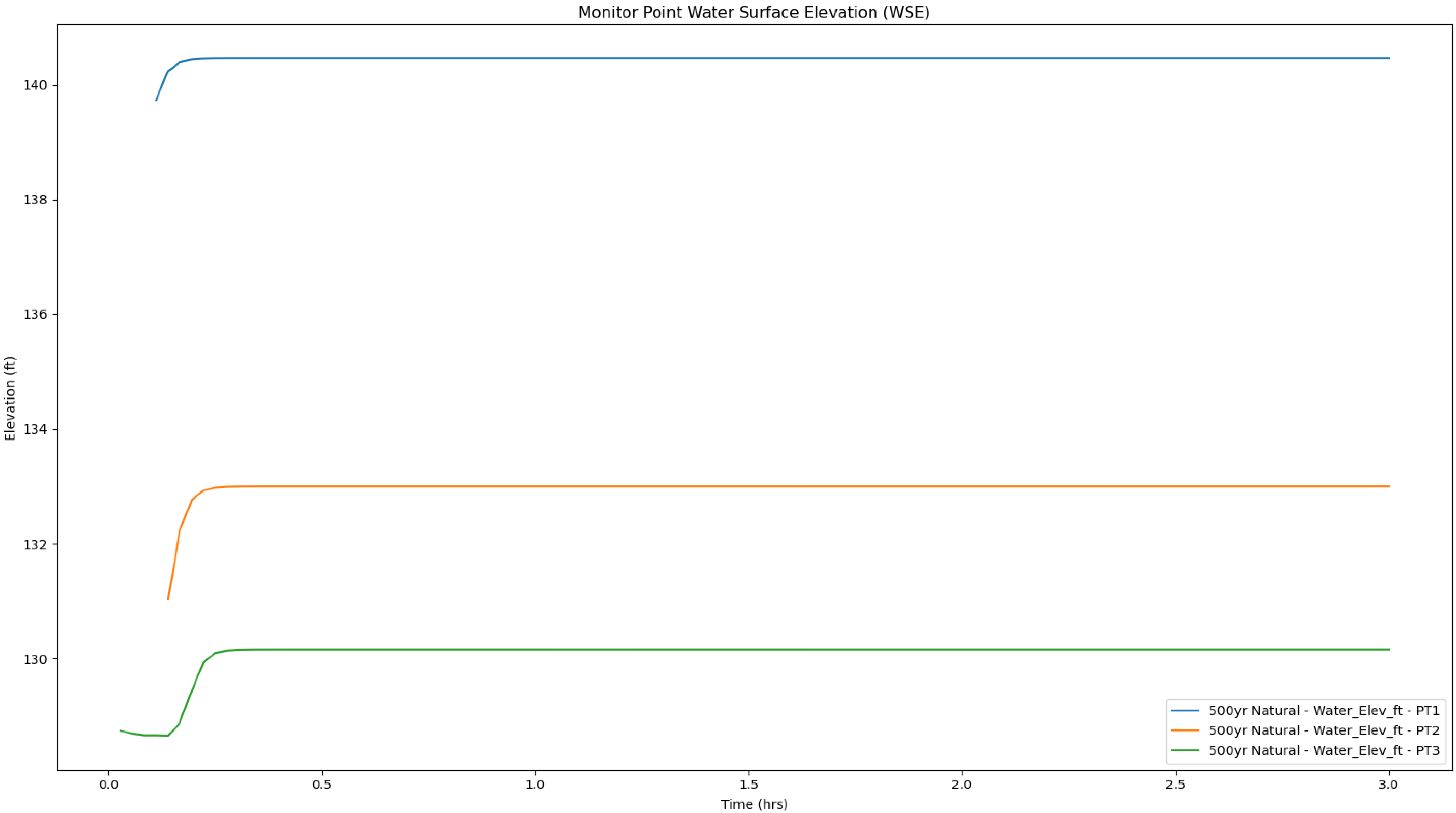


Figure I.15: Natural conditions 500-year monitor points

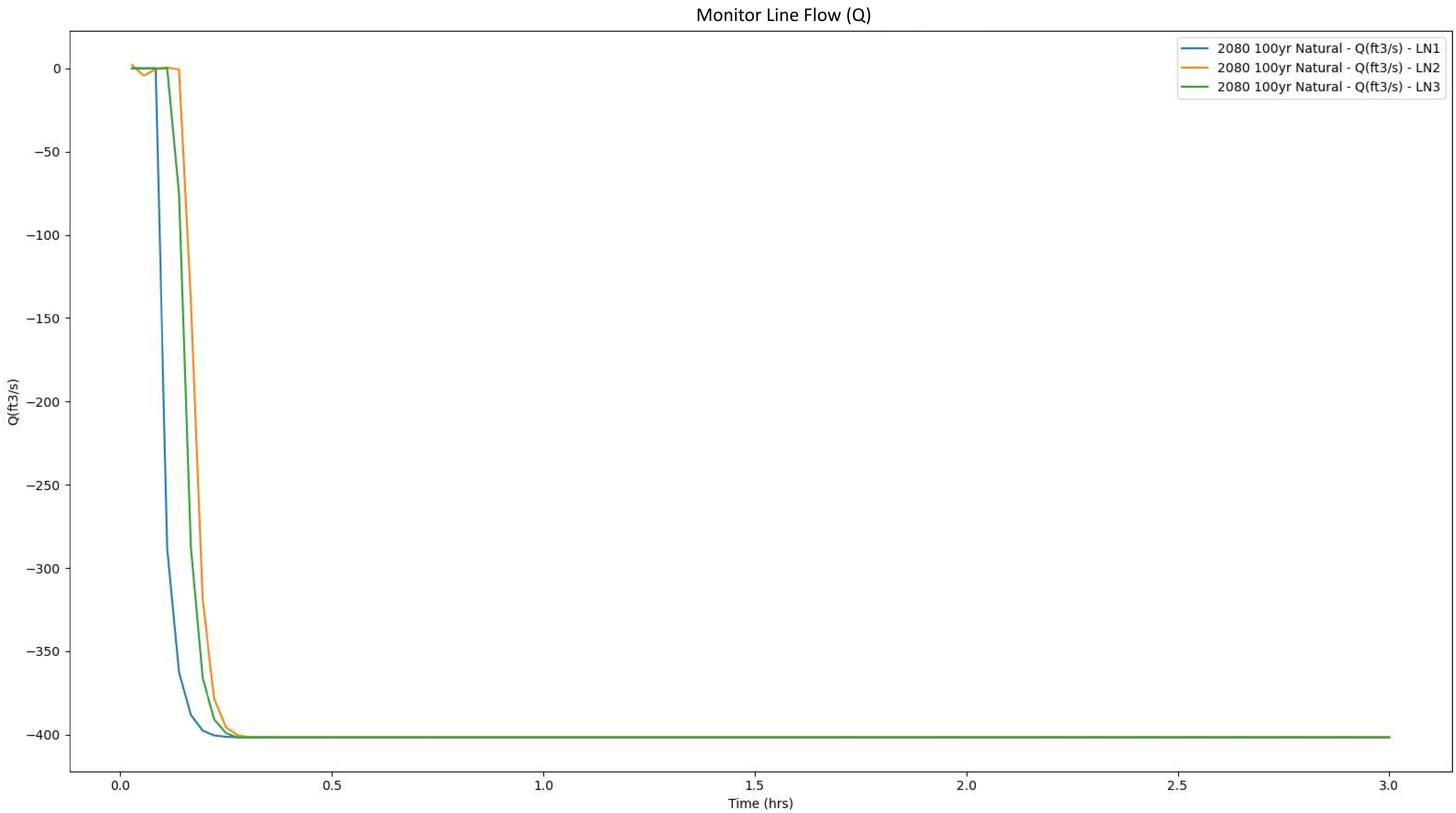


Figure I.16: Natural conditions 2080 predicted 100-year monitor lines

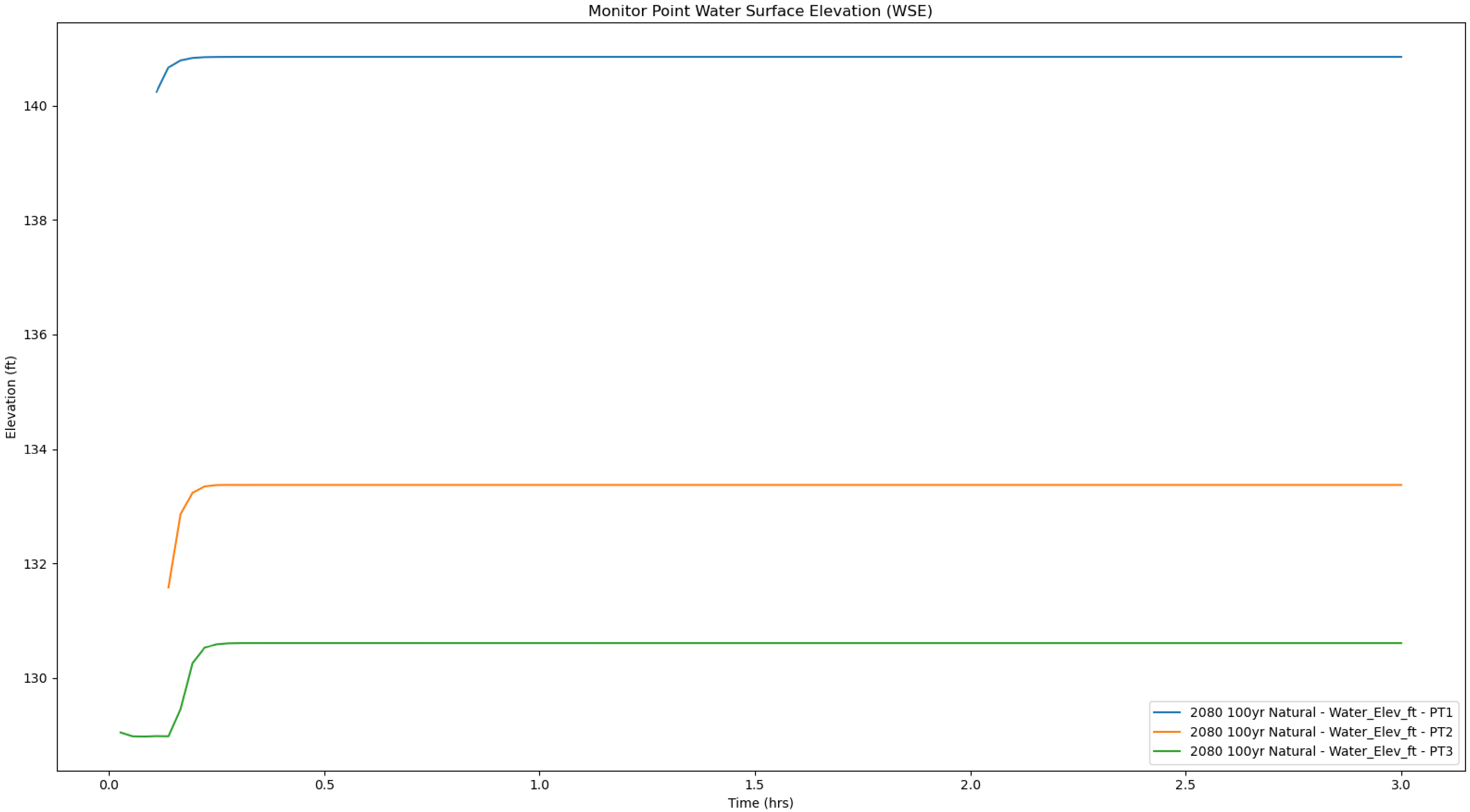


Figure I.17: Natural conditions 2080 predicted 100-year monitor points

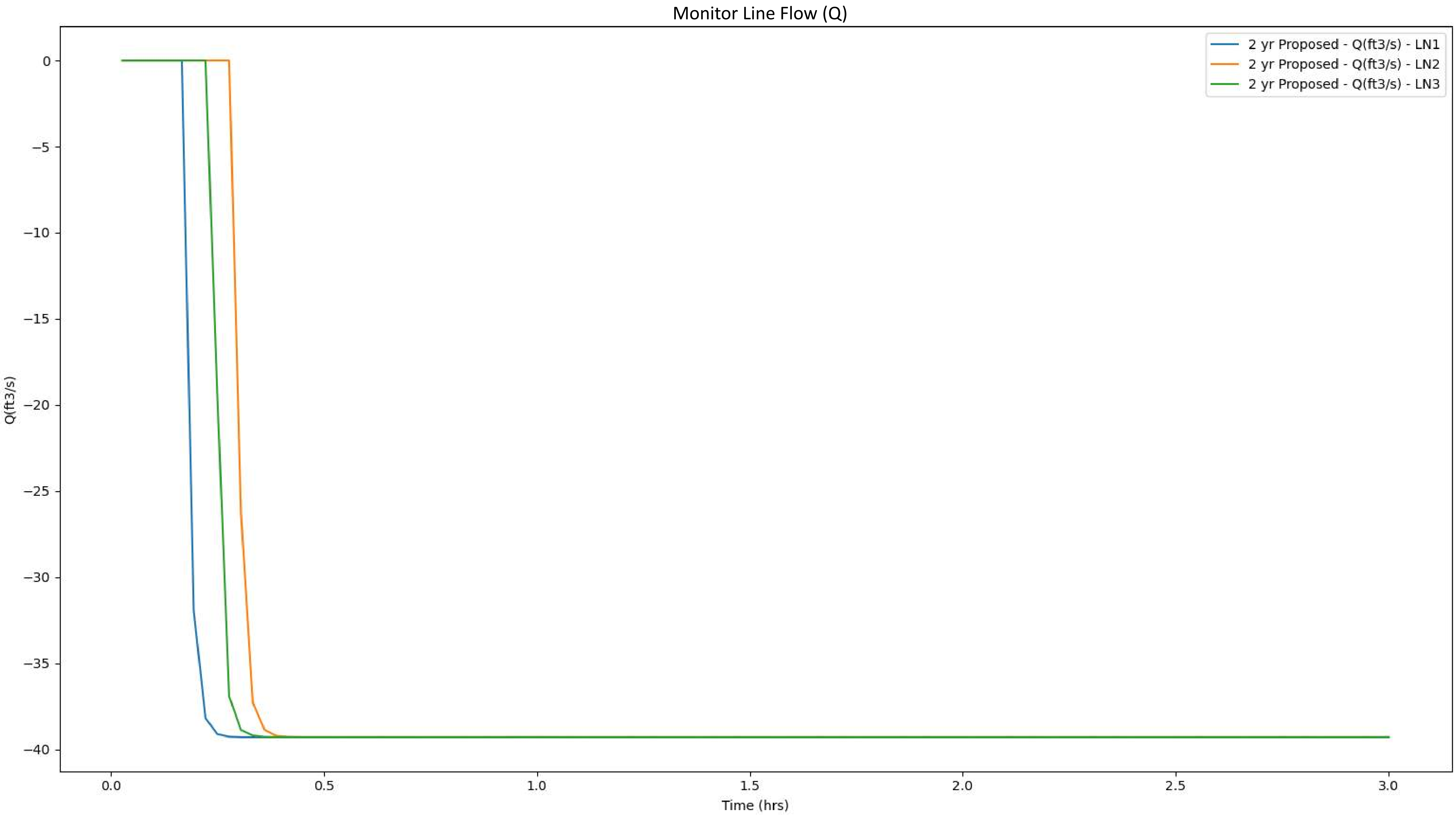


Figure I.18: Proposed conditions 2-year monitor lines

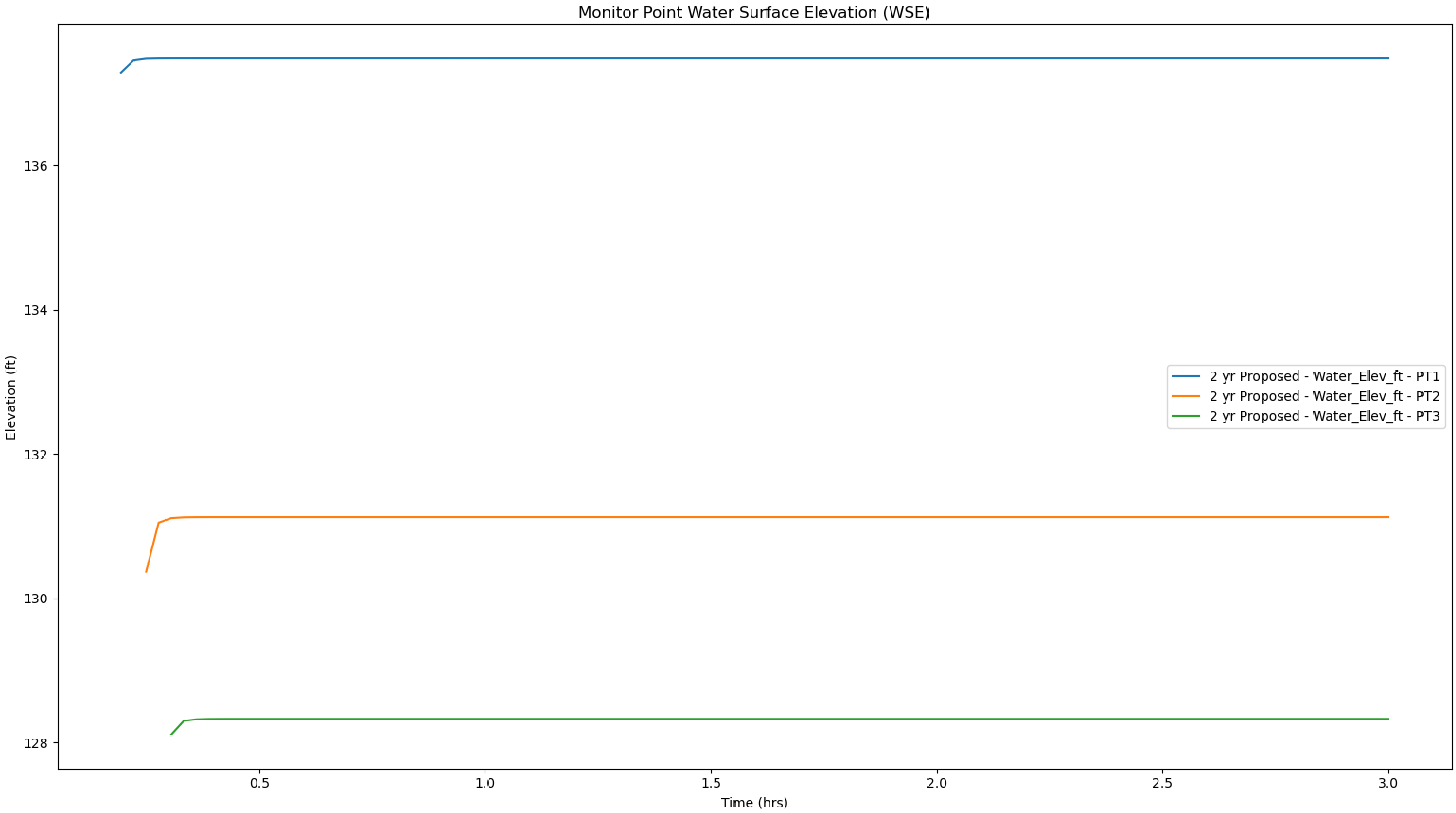


Figure I.19: Proposed conditions 2-year monitor points

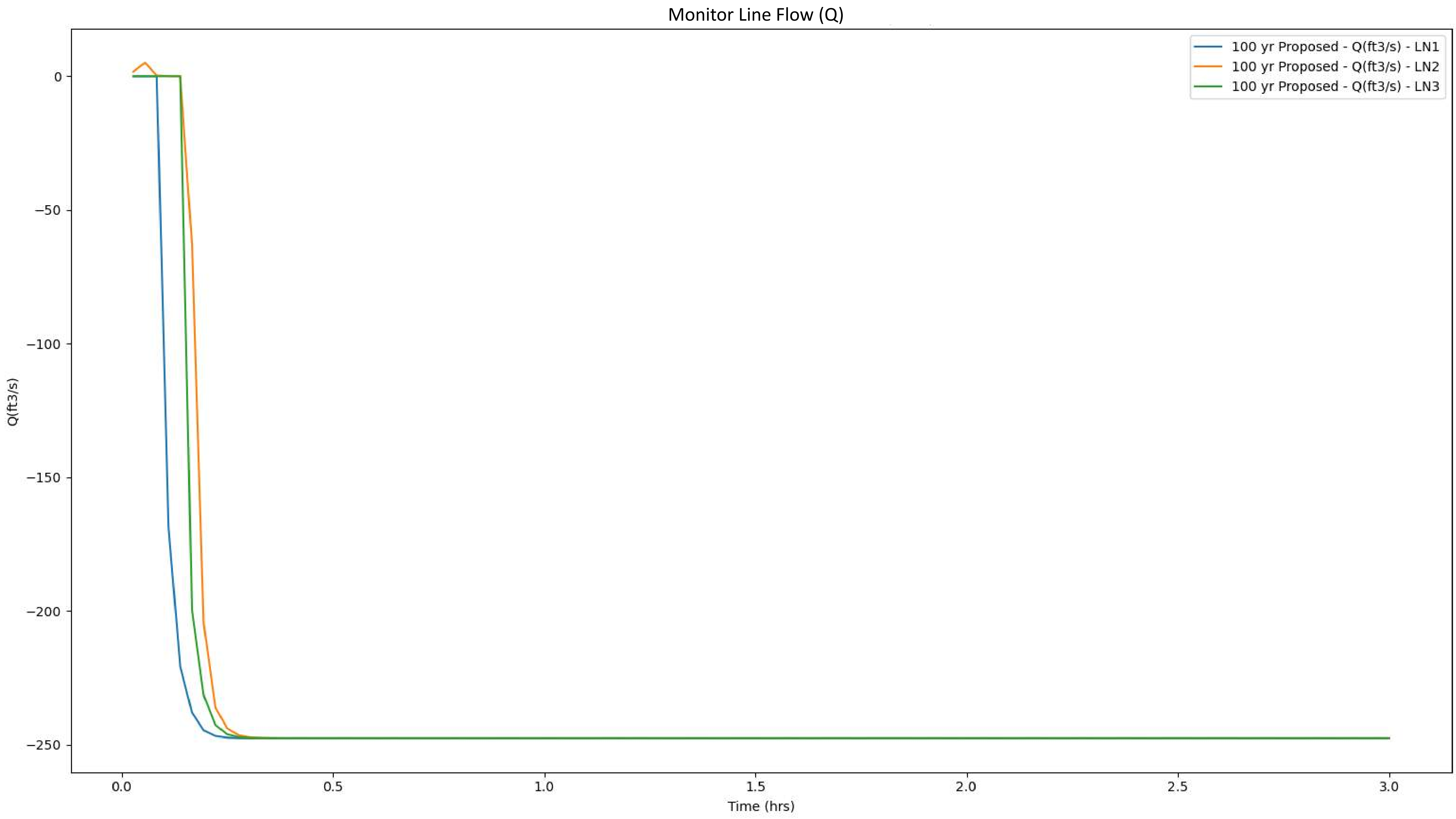


Figure I.20: Proposed conditions 100-year monitor lines

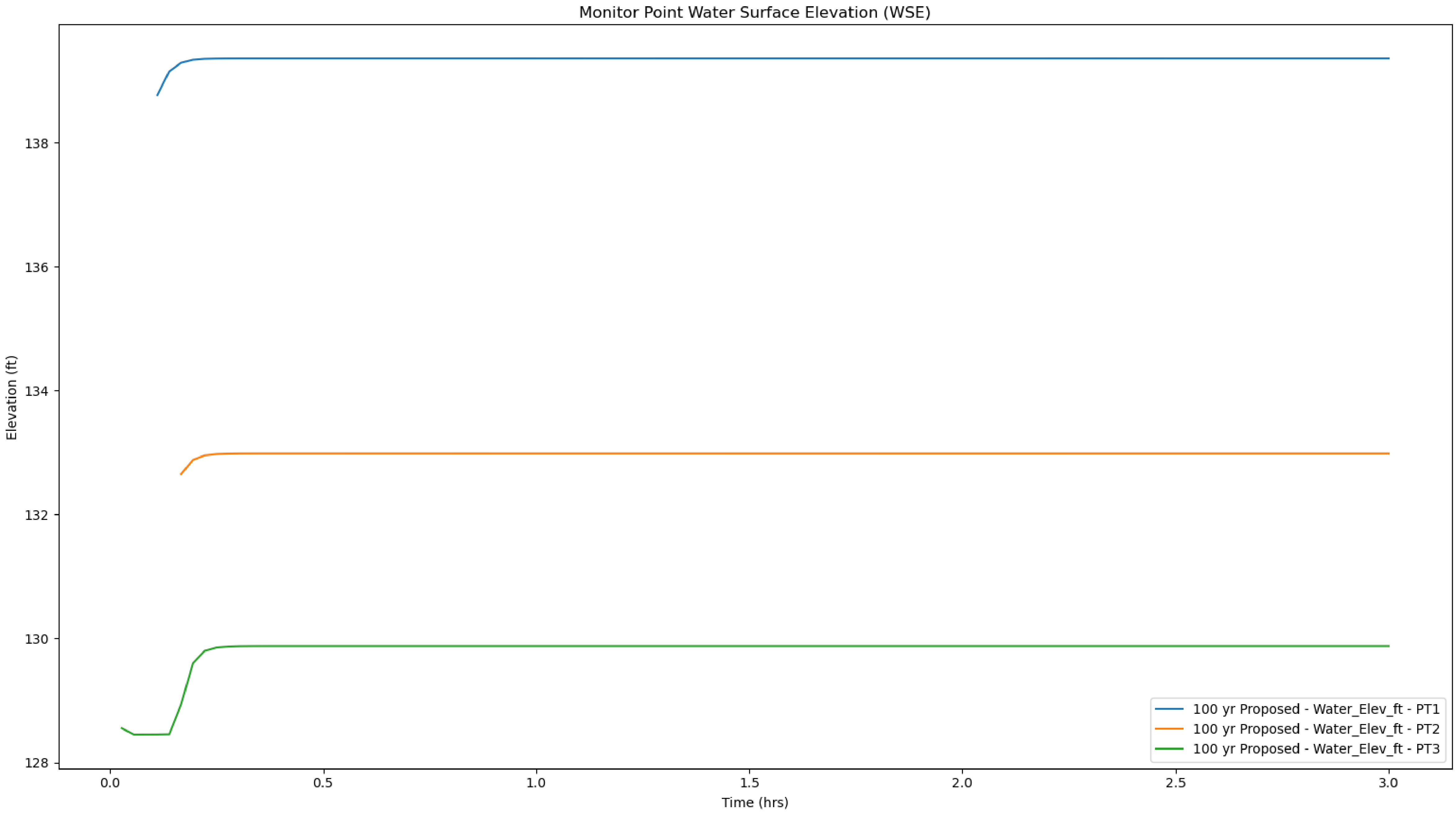


Figure I.21: Proposed conditions 100-year monitor points

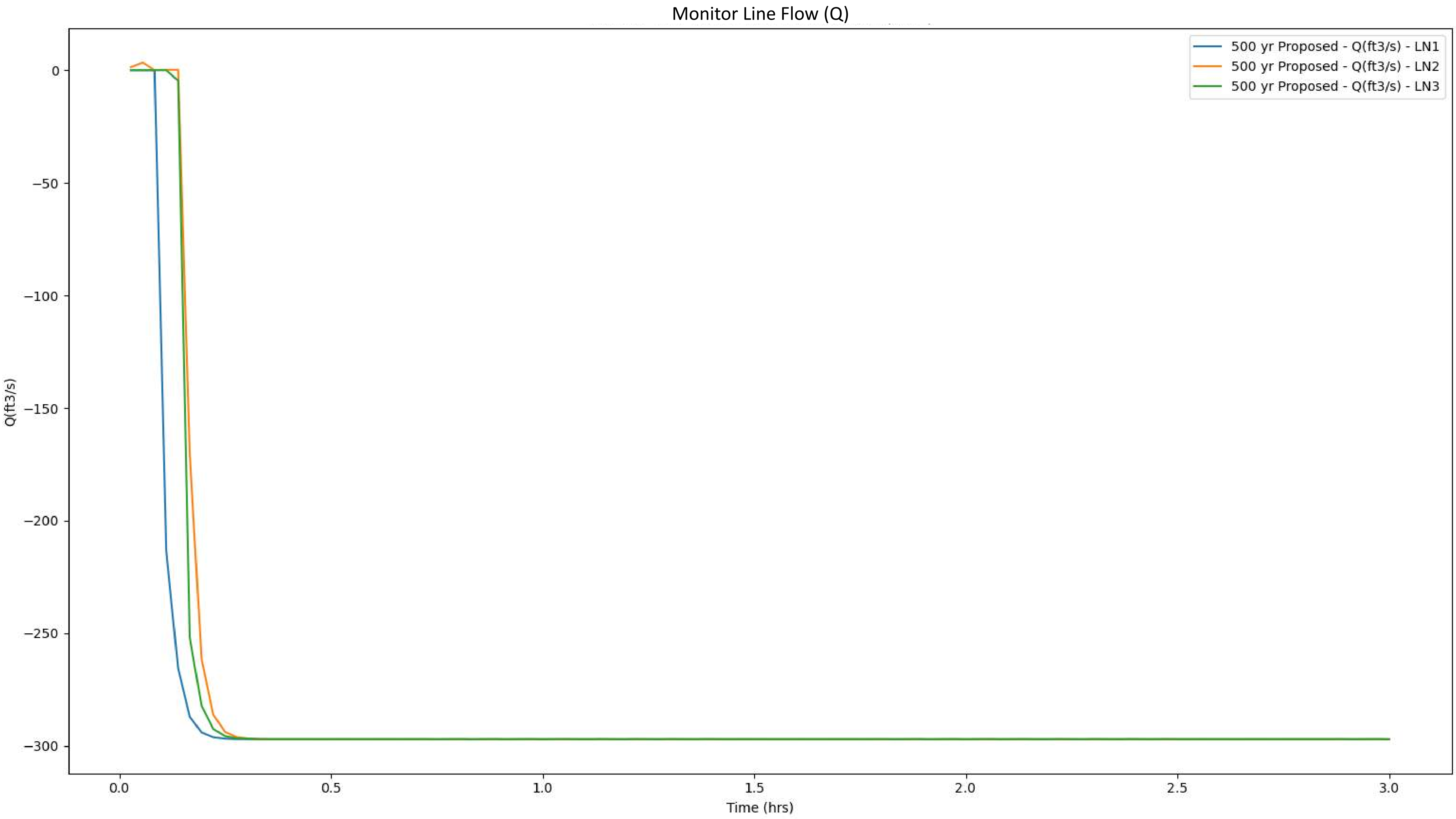


Figure I.22: Proposed conditions 500-year monitor lines

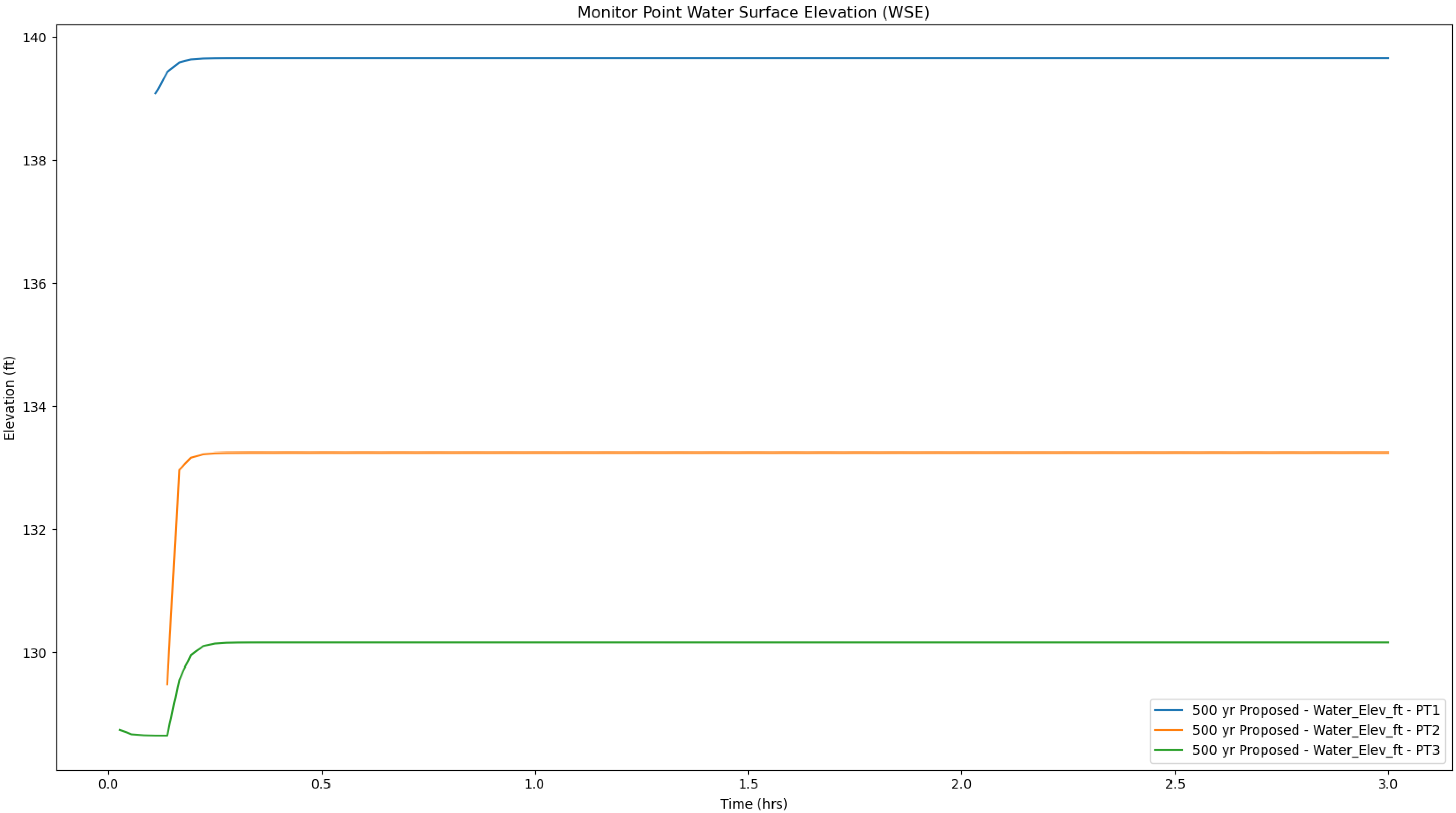


Figure I.23: Proposed conditions 500-year monitor points

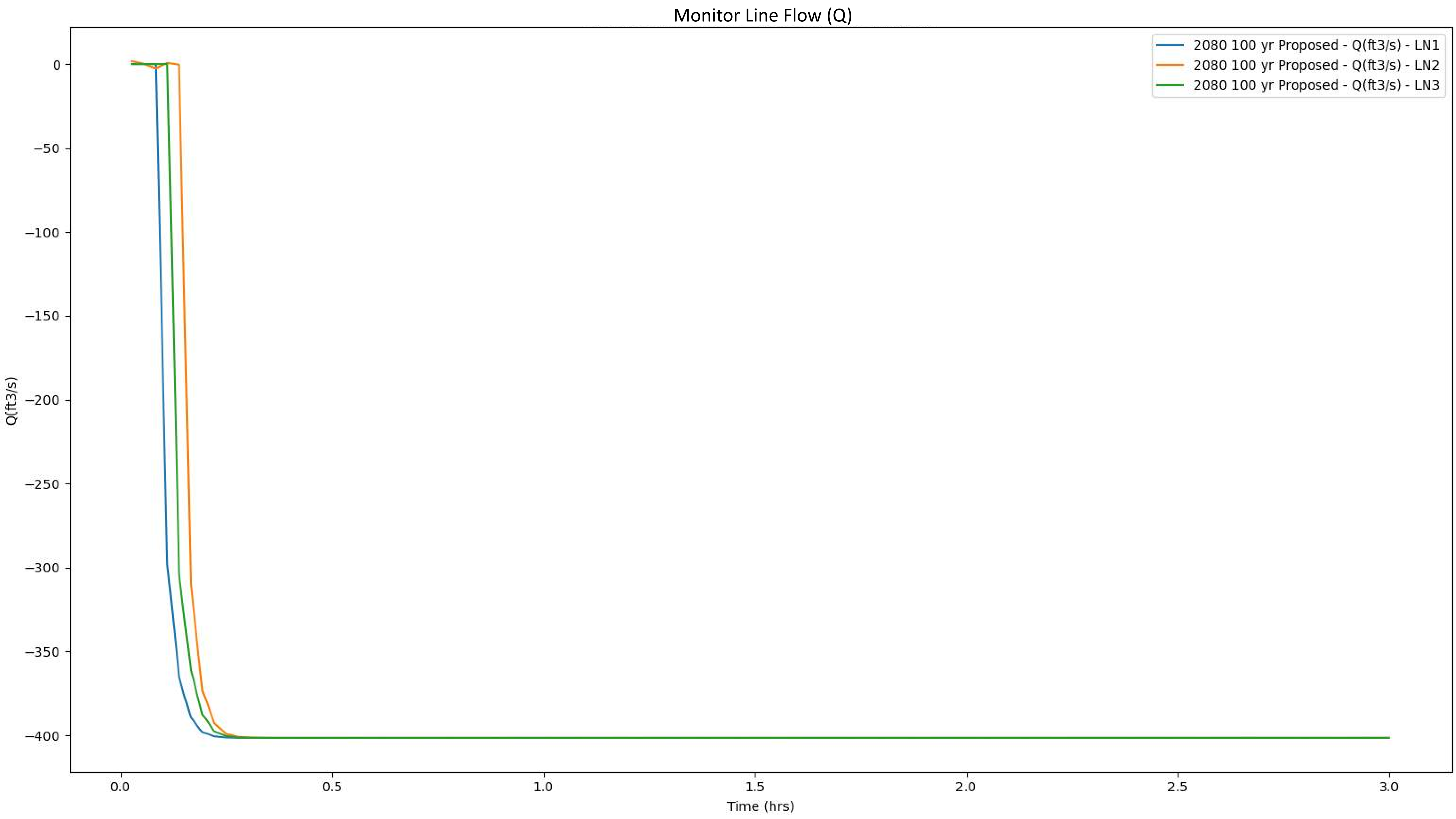


Figure I.24: Proposed conditions 2080 predicted 100-year monitor lines

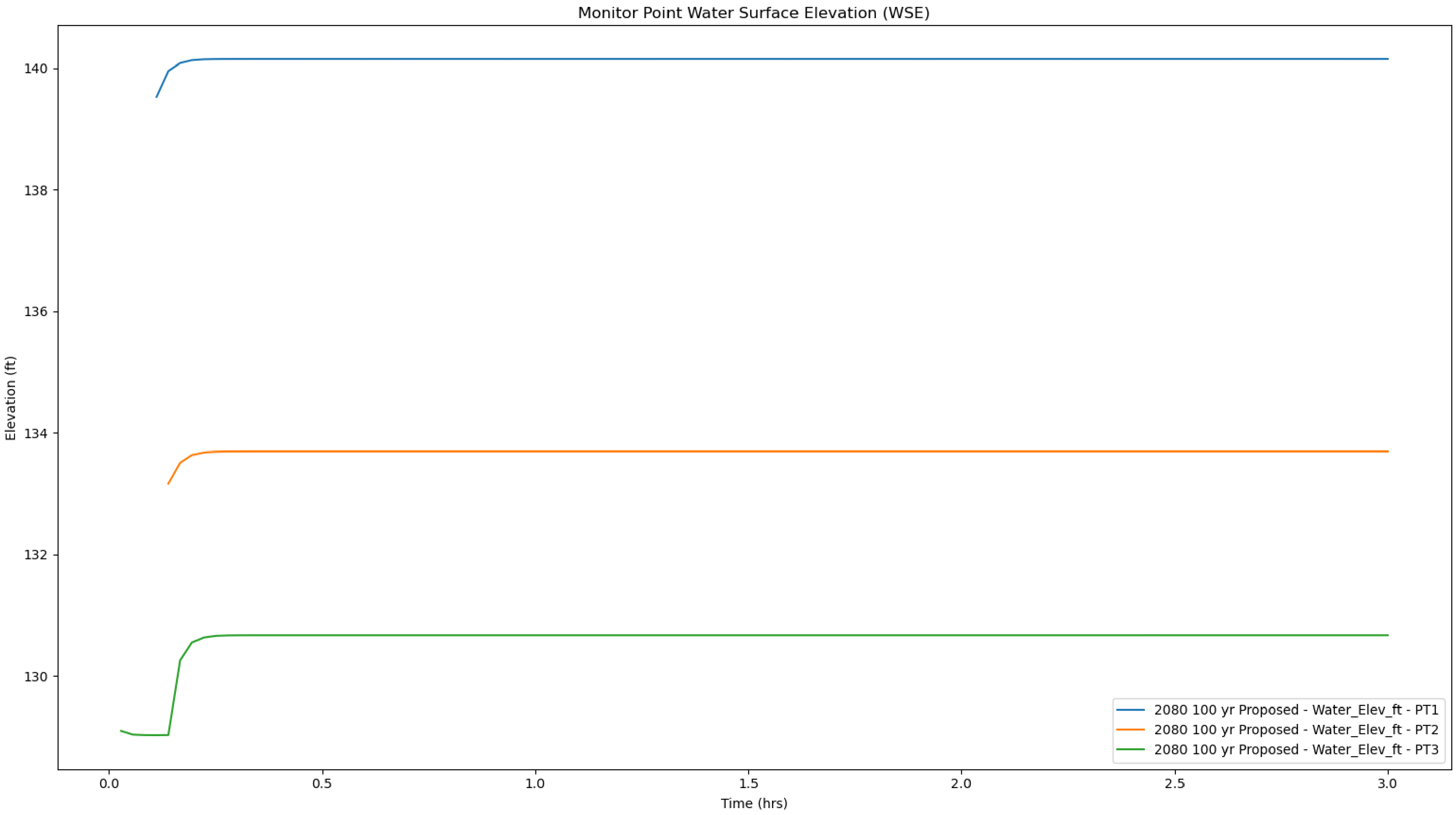


Figure I.25: Proposed conditions 2080 predicted 100-year monitor points

Appendix J: Reach Assessment (Not Used)

Appendix K: Scour Calculations (Preliminary)

SMS Bridge Scour Coverage Figures

Scour Arcs
Contracted Section Arc
Approach Arc
Centerline Arc
Bank Arc
Abutment Toe Arc
Channel Width
Critical Velocity Index
2.0
1.0
0.0
Scour Design Flood
(500-year event)
Big Scandia Creek
3+00
4+00
5+00
6+00
7+00
8+00
N
Feet (U.S. Survey)
0
50
100

Scour Arcs
Contracted Section Arc
Approach Arc
Centerline Arc
Bank Arc
Abutment Toe Arc
Channel Width
Critical Velocity Index
2.0
1.0
0.0
Scour Check Flood
(2080 100-year event)
Big Scandia Creek
3+00
4+00
5+00
6+00
7+00
8+00
N
Feet (U.S. Survey)
0
50
100

Hydraulic Toolbox Model Output

Contraction Scour

Contraction Scour

2-year Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.12	ft	
D50	22.860000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	2.19	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	4.80	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	37.72	cfs	
Bottom Width in Contracted Section	12.07	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	0.99	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.018896	ft/ft	
Discharge in Contracted Section	37.72	cfs	
Discharge Upstream that is Transporting Sediment	38.21	cfs	
Width in Contracted Section	12.07	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	15.60	ft	
Depth Prior to Scour in Contracted Section	0.99	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	28.575000	mm	
Average Depth in Contracted Section after Scour	0.65	ft	
Scour Depth	-0.34	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	0.82	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	1.30	ft	
Scour Depth	0.31	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.0867	lb/ft^2	
Shear Required for Movement of D50 Particle	0.3001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.34	ft	Negative values imply 'zero' ...

Contraction Scour

10-year Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	1.66	ft	
D50	30.480000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	3.14	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	5.64	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	105.50	cfs	
Bottom Width in Contracted Section	16.25	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	1.52	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.019231	ft/ft	
Discharge in Contracted Section	105.50	cfs	
Discharge Upstream that is Transporting Sediment	111.66	cfs	
Width in Contracted Section	16.25	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	21.39	ft	
Depth Prior to Scour in Contracted Section	1.52	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	38.100000	mm	
Average Depth in Contracted Section after Scour	1.12	ft	
Scour Depth	-0.40	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.01	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	1.89	ft	
Scour Depth	0.37	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.2217	lb/ft^2	
Shear Required for Movement of D50 Particle	0.4001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.40	ft	Negative values imply 'zero' ...

Contraction Scour

25-year Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	2.10	ft	
D50	30.480000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	3.61	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	5.87	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	145.31	cfs	
Bottom Width in Contracted Section	16.25	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	1.87	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.019493	ft/ft	
Discharge in Contracted Section	145.31	cfs	
Discharge Upstream that is Transporting Sediment	162.31	cfs	
Width in Contracted Section	16.25	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	21.39	ft	
Depth Prior to Scour in Contracted Section	1.87	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	38.100000	mm	
Average Depth in Contracted Section after Scour	1.47	ft	
Scour Depth	-0.40	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.15	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	2.28	ft	
Scour Depth	0.41	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.3066	lb/ft^2	
Shear Required for Movement of D50 Particle	0.4001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.40	ft	Negative values imply 'zero' ...

Contraction Scour

50-year Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	2.45	ft	
D50	30.480000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	3.88	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	6.02	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	178.34	cfs	
Bottom Width in Contracted Section	16.25	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	2.14	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.019740	ft/ft	
Discharge in Contracted Section	178.34	cfs	
Discharge Upstream that is Transporting Sediment	203.38	cfs	
Width in Contracted Section	16.25	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	21.39	ft	
Depth Prior to Scour in Contracted Section	2.14	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	38.100000	mm	
Average Depth in Contracted Section after Scour	1.75	ft	
Scour Depth	-0.39	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.25	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	2.61	ft	
Scour Depth	0.47	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.3686	lb/ft^2	
Shear Required for Movement of D50 Particle	0.4001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.39	ft	Negative values imply 'zero' ...

Contraction Scour

100-year Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	2.64	ft	
D50	30.480000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	4.00	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	6.10	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	199.62	cfs	
Bottom Width in Contracted Section	16.25	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	2.30	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.019793	ft/ft	
Discharge in Contracted Section	199.62	cfs	
Discharge Upstream that is Transporting Sediment	225.88	cfs	
Width in Contracted Section	16.25	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	21.39	ft	
Depth Prior to Scour in Contracted Section	2.30	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	38.100000	mm	
Average Depth in Contracted Section after Scour	1.93	ft	
Scour Depth	-0.37	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.30	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	2.83	ft	
Scour Depth	0.53	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.4030	lb/ft^2	
Shear Required for Movement of D50 Particle	0.4001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.37	ft	Negative values imply 'zero' ...

Contraction Scour

500-year Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	2.89	ft	
D50	30.480000	mm	0.2 mm is the lower limit for ...
Average Velocity Upstream	4.15	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s...	6.19	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	231.54	cfs	
Bottom Width in Contracted Section	16.25	ft	Width should exclude pier wi...
Depth Prior to Scour in Contracted Section	2.54	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.019748	ft/ft	
Discharge in Contracted Section	231.54	cfs	
Discharge Upstream that is Transporting Sediment	256.35	cfs	
Width in Contracted Section	16.25	ft	Remove widths occupied by ...
Width Upstream that is Transporting Sediment	21.39	ft	
Depth Prior to Scour in Contracted Section	2.54	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b...	38.100000	mm	
Average Depth in Contracted Section after Scour	2.19	ft	
Scour Depth	-0.34	ft	Negative values imply 'zero' ...
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.35	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	3.15	ft	
Scour Depth	0.62	ft	Negative values imply 'zero' ...
Shear Applied to Bed by Live-Bed Scour	0.4542	lb/ft^2	
Shear Required for Movement of D50 Particle	0.4001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.34	ft	Negative values imply 'zero' ...

Contraction Scour

2080 100-year Contraction Scour

Computation Method: Clear-Water and Live-Bed Scour

Parameter	Value	Units	Notes
Input Parameters			
Average Depth Upstream of Contraction	3.30	ft	
D50	30.480000	mm	0.2 mm is the lower limit for …
Average Velocity Upstream	4.45	ft/s	
Results of Scour Condition			
Critical velocity above which bed material of size D and s…	6.33	ft/s	
Contraction Scour Condition	Clear Water		
Clear Water Input Parameters			
Discharge in Contracted Section	296.72	cfs	
Bottom Width in Contracted Section	16.25	ft	Width should exclude pier wi…
Depth Prior to Scour in Contracted Section	2.98	ft	
Live Bed & Clear Water Input Parameters			
Temperature of Water	60.00	ºF	
Slope of Energy Grade Line at Approach Section	0.019469	ft/ft	
Discharge in Contracted Section	296.72	cfs	
Discharge Upstream that is Transporting Sediment	313.45	cfs	
Width in Contracted Section	16.25	ft	Remove widths occupied by …
Width Upstream that is Transporting Sediment	21.39	ft	
Depth Prior to Scour in Contracted Section	2.98	ft	
Unit Weight of Water	62.40	lb/ft^3	
Unit Weight of Sediment	165.00	lb/ft^3	
Results of Clear Water Method			
Diameter of the smallest nontransportable particle in the b…	38.100000	mm	
Average Depth in Contracted Section after Scour	2.71	ft	
Scour Depth	-0.27	ft	Negative values imply 'zero' …
Results of Live Bed Method			
k1	0.640000		
Shear Velocity	1.44	ft/s	
Fall Velocity	1.64	ft/s	
Average Depth in Contracted Section after Scour	3.75	ft	
Scour Depth	0.77	ft	Negative values imply 'zero' …
Shear Applied to Bed by Live-Bed Scour	0.5587	lb/ft^2	
Shear Required for Movement of D50 Particle	0.4001	lb/ft^2	
Recommendations			
Recommended Scour Depth	-0.27	ft	Negative values imply 'zero' …

Abutment Scour

Abutment Scour

2-year Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutmen...		
Unit Discharge, Upstream in Main Channel (q1)	2.45	cfs/ft	
Unit Discharge in Constricted Area (q2)	3.12	cfs/ft	
D50	22.860000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.12	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	1.53	ft	Depth at Abutment Toe
Results			
q2 / q1	1.28		
Average Velocity Upstream	2.19	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	4.80	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.76		
Flow Depth including Contraction Scour	0.70	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	1.24	ft	Including the long-term scour de...
Scour Hole Depth	-0.29	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...

Abutment Scour

10-year Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutmen...		
Unit Discharge, Upstream in Main Channel (q1)	5.22	cfs/ft	
Unit Discharge in Constricted Area (q2)	6.49	cfs/ft	
D50	30.480000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	1.66	ft	
Define Shear Stress of Floodplain			
Flow Depth prior to Scour	2.34	ft	Depth at Abutment Toe
Results			
q2 / q1	1.24		
Average Velocity Upstream	3.14	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	5.64	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.75		
Flow Depth including Contraction Scour	1.21	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	2.13	ft	Including the long-term scour de...
Scour Hole Depth	-0.21	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...

Abutment Scour

25-year Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutmen...		
Unit Discharge, Upstream in Main Channel (q1)	7.59	cfs/ft	
Unit Discharge in Constricted Area (q2)	8.94	cfs/ft	
D50	30.480000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	2.10	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	2.69	ft	Depth at Abutment Toe
Results			
q2 / q1	1.18		
Average Velocity Upstream	3.61	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	5.87	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.72		
Flow Depth including Contraction Scour	1.60	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	2.75	ft	Including the long-term scour de...
Scour Hole Depth	0.06	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	0.06	ft	

Abutment Scour

50-year Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutmen...		
Unit Discharge, Upstream in Main Channel (q1)	9.51	cfs/ft	
Unit Discharge in Constricted Area (q2)	10.98	cfs/ft	
D50	30.480000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	2.45	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	2.96	ft	Depth at Abutment Toe
Results			
q2 / q1	1.15		
Average Velocity Upstream	3.88	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	6.02	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.70		
Flow Depth including Contraction Scour	1.90	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	3.23	ft	Including the long-term scour de...
Scour Hole Depth	0.27	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	0.28	ft	

Abutment Scour

100-year Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutmen...		
Unit Discharge, Upstream in Main Channel (q1)	10.56	cfs/ft	
Unit Discharge in Constricted Area (q2)	12.29	cfs/ft	
D50	30.480000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	2.64	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	3.12	ft	Depth at Abutment Toe
Results			
q2 / q1	1.16		
Average Velocity Upstream	4.00	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	6.10	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.71		
Flow Depth including Contraction Scour	2.09	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	3.58	ft	Including the long-term scour de...
Scour Hole Depth	0.46	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	0.48	ft	

Abutment Scour

500-year Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutmen...		
Unit Discharge, Upstream in Main Channel (q1)	11.99	cfs/ft	
Unit Discharge in Constricted Area (q2)	14.25	cfs/ft	
D50	30.480000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	2.89	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	3.36	ft	Depth at Abutment Toe
Results			
q2 / q1	1.19		
Average Velocity Upstream	4.15	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	6.19	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.73		
Flow Depth including Contraction Scour	2.38	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	4.11	ft	Including the long-term scour de...
Scour Hole Depth	0.75	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	0.78	ft	

Abutment Scour

2080 100-year Abutment Scour

Computation Method: NCHRP

Parameter	Value	Units	Notes
Input Parameters			
Scour Condition	Compute		
Scour Condition Location	Type a (Main Channel)		
Abutment Type	Vertical-wall abutmen...		
Unit Discharge, Upstream in Main Channel (q1)	14.66	cfs/ft	
Unit Discharge in Constricted Area (q2)	18.26	cfs/ft	
D50	30.480000	mm	0.2 mm is the lower limit for coh...
Upstream Flow Depth	3.30	ft	
Define Shear Stress of Floodplain	☐		
Flow Depth prior to Scour	3.80	ft	Depth at Abutment Toe
Results			
q2 / q1	1.25		
Average Velocity Upstream	4.45	ft/s	
Critical Velocity above which Bed Materal of Size D and Sm...	6.33	ft/s	
Scour Condition	Clear Water		
Scour Condition	a (Main Channel)		
Amplification Factor	1.75		
Flow Depth including Contraction Scour	2.94	ft	
Scour depth from Long-Term Degradation calculations	0.00	ft	
Maximum Flow Depth including Abutment Scour	5.16	ft	Including the long-term scour de...
Scour Hole Depth	1.36	ft	Negative values imply 'zero' sco...
Scour Hole			
Angle of Repose	44.00	degrees	
Ratio of Bottom Width of Scour Hole to Scour Hole Depth	0.00		1.0 means the bottom width will ...
Scour Hole Bottom Width	0.00	ft	
Scour Hole Top Width	1.41	ft	

Appendix L: Floodplain Analysis (Not Used)

Appendix M: Scour Countermeasure Calculations (FHD ONLY)